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Accessing Background Knowledge To Build Mathematical Vocabulary

Stephanie Sodeman
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This paper examines the benefits of accessing knowledge to build background knowledge in mathematics. Various methods of vocabulary instruction are explained and examined. Research of vocabulary instruction in math speaks to the need for educators to explicitly teach vocabulary in adding to skills if order for students to develop as mathematicians. An elementary school classroom teacher examined two mathematical units, one with clear vocabulary teaching and one without a focus on vocabulary. The data demonstrates the benefits of explicit vocabulary instruction as student achievement raised 39% on end of unit assessments.

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Accessing Background Knowledge to Build Mathematical Vocabulary

Building background knowledge and how it relates to vocabulary development in math is crucial for students' development and understanding of mathematical concepts. In order to build background knowledge, students need an understanding of vocabulary terms in order to conceptualize and connect new learning to previous learning for long term memory retrieval. In is crucial that educators find ways to access prior knowledge (schema) in order to connect it to new learning through a rigorous curriculum that contains a wide range of vocabulary enrichment tools. This vocabulary instruction can not be incidental. Research demonstrates the need for vocabulary instruction in classrooms every day, especially in the area of math. According to Monroe and Orme (2002) "Development of vocabulary is crucial to any experience involving language. Because of the high incidence of unfamiliar vocabulary in mathematics, teaching unknown words becomes central to mathematics literacy" (p. 141).

Without explicit vocabulary instruction, students loose the ability to make connections between concepts and previously learned material. Research acknowledges that mathematics is a discipline in which reading is extremely difficult, "with more concepts per word, per sentence, and per paragraph than any other area" (Schell, 1982, p. 544).

It is not enough to just acknowledge the important of vocabulary instruction in classrooms. Teachers must be instructed on how to teach in a variety of ways in order to help students to develop an extensive mathematical vocabulary from a young age in their permanent memory. As students grow and develop their mathematical vocabulary, they need to be able to access vocabulary that was developed and from a very early age. This will allow students to make connections with information and further more will extend that knowledge as they begin to learn to work with mathematical concepts with a greater difficulty. Failure to do so will result in students who lack the connections between concepts and the ability to access prior learning.

Literature Review

Learning new words and concepts require an active process in which connections are made. Through explicit vocabulary instruction, students process new words to extend understanding in order to connect it to another word or concept already known. These connections lay the framework for future learning and understanding as they allow students to develop more than an abstract understanding of words. According to Marzano (2004) "the research literature supports one compelling fact: what students already know about the content is one of the strongest indicators of how well they will learn new information relative to the content" (p. 49).

There is a need for a variety of teaching experiences that allow students to practice, apply, and discuss their word knowledge as a means for students to learn and retain new vocabulary that will be stored in their permanent memory. Students should be actively learning new words and work to expand their understanding of words through instruction that is based on active processing. Students must go beyond just memorizing definitions. Instead, they must integrate the word meaning with their existing knowledge in order to build representations of vocabulary in multiple conceptual situations. The literature demonstrates a variety of instructional techniques that allow students to develop deeper meanings and understanding of math vocabulary. This literature review hopes to introduce some of those instructional strategies and pedagogy. As students expand their experimental and conceptual backgrounds, they expand and refine their knowledge of words (Nichols & Rupley, 2004).

Background Knowledge

In order to understand how background knowledge is acquired, we must know how memory is stored in our brain. Information is stored in our brain as "file folders" or categories. As students learn new information, or actively processing vocabulary, the brain works to find prior knowledge so that it may link new learning to previous learning. This helps students to organize information into categories of information.

Vocabulary instruction that is geared to the active process of learning and connects new information to previously learned experiences provides the means for students to make the connections between new words and their past experiences (Logan, Nichols & Rupley, 1999) According to Vacca and Vacca (1999), student's prior knowledge is "the single most important resource in learning with texts" (p. 9). Reading and learning are constructive processes in which the learner actively draws on prior learning and experiences to make sense of new information being presented.

Memory

Memory is often thought of in two categories: long and short term. Some researches, such as Anderson (1995), suggest that the distinction between long and short term memory have been replaced with the theory that there is only one type of memory, and it has different functions: sensory memory, permanent memory and working memory.

Figure 1 demonstrates the three functions of memory described by Anderson. Sensory memory is a short term storage place. We do not store all information that enters our short term memory and therefore much information is lost. Information that is stored then becomes part of our working memory. This information is held in our working memory to be readily accessed or is transferred over to our permanent memory.

Figure 1

Three Functions of Memory

Sensory Memory

Sensory memory deals with a short term or temporary storage of data from the senses. Anderson (1995) describes sensory memory as follows:

> Sensory memory is capable of story more or less complete records of what has been encountered for brief periods of times, during which people can note relationships among the elements and encode the elements in a more permanent memory. If the information in sensory memory is not encoded in the brief time before it decays, it is lost. What subjects encode depends on what they are paying attention to. The environment typically offers much more

> information at one time than we can attend to and encode. Therefore, much of what enters our sensory system results in no permanent record. (p. 160)

Sensory memory is a temporary warehouse for information from our senses. Since we are unable to process all the information from our senses, we pick and chose information to store and all left over information is lost.

Working Memory

As noted in figure 1, working memory can receive information from our temporary data storage warehouse, our sensory memory, or from our permanent memory, where information is stored permanently, or from both. There is no limit to how long information can be stored in our working memory warehouse as long as it stays active. The quality of information and type of processing that continues while information remains in our working memory helps determine whether information will be moved into our permanent memory. If this process is done well, information is moved to our permanent memory, while it will not move if the process is not completed successfully. There are a variety of ways to determine whether information will move into our permanent memory successfully (Marzano, 2004).

One way to increase the likelihood of information transitioning from working memory to permanent is for students to be engaged in using information repeatedly. In simple terms, the more times we engage information in working memory, the higher the probability that it will be embedded in permanent memory (Marzano, 2004).

The depth of processing information is another aspect of effecting processing of working memory. In this type of process, students would take the background knowledge they already have, such as birds, and add details to this category of information they already have, such as types of birds or specific characteristics of birds. Adding details helps connect this working information to successfully moving to permanent information.

Elaboration is another aspect of effort processing and is similar to adding depth to processing. Adding depth of processing requires one to add details to memory, while elaboration requires making new or varied connections with information.

Permanent Memory

Permanent memory is memory that has been stored and can be readily accessed. Overall, we know and understand information that is part of information in our permanent memory. Therefore, information that is in our permanent memory is our background knowledge (Marzano, 2004).

Summary of Memory

If information is to be part of our background knowledge, it must reach our permanent memory. The quality in which we process information determines how frequently memory from our working memory will transition into our permanent memory. Using strategies such as using information frequently, adding depth to our processing, and making connections to elaborate information will help students build background knowledge. As a result, in order to build background knowledge, students need to participate and active processing vocabulary activities.

Direct Instruction

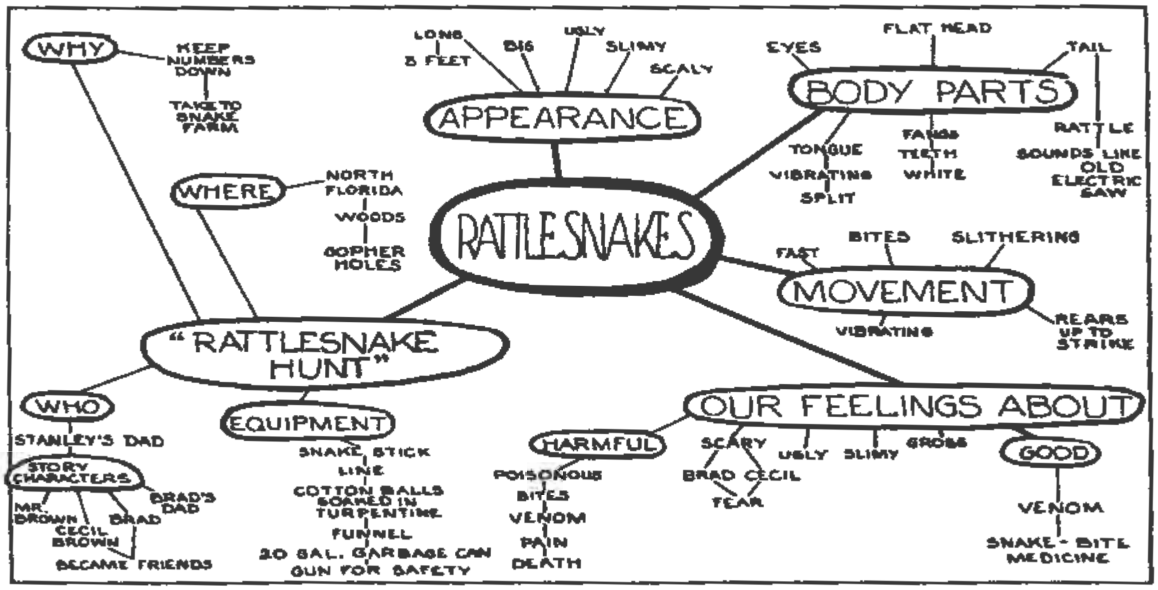
There are a variety of direct instruction techniques that have been noted as useful in the classroom to enhance instruction and build vocabulary though not all have been found to be effective. It is imperative that classrooms throughout the ages use their strategies to instruct students and aide in their vocabulary development. Miller and Gildea (1987) noted that many classrooms throughout the country made students develop their vocabularies through looking up definitions in a dictionary. They concluded that looking words up in the dictionary and then writing them in a sentence was pedagogically useless (Irvin, 2001).

Techniques such as semantic mapping, semantic feature analysis, graphic organizers, The Frayer Model, concept mapping and word maps are used to access background knowledge and build vocabulary. Through these techniques, students are actively processing knowledge to build background knowledge, make connections, and help transition information from working memory into permanent memory. As educators guide students, teachers can assist students by guiding their decision making until effect strategies become automatic (Irvin, 2001, p. 41).

Semantic Mapping

Semantic mapping is a strategy that is noted for its ability to organize information into graphic form. Figure 2 is a rattlesnake semantic map completed by students in a sixth grade classroom. This pre-reading activity was used with a small group of readers in order to access their prior knowledge of rattlesnakes in order to build vocabulary and increase comprehension (Heimlich and Pittelman, 1986).

Figure 2: Semantic Map:



Semantic mapping is a procedure in which the teacher writes a word representing an important concept of the chalkboard or an overhead transparency and asks students to list as many related words as possible, putting them in broad categories as they do so (Rekrut, 1996). This method of instruction activates prior knowledge and builds on student's prior knowledge base. (Heimlich & Pittelman, 1986) Through semantic mapping, students become active readers by triggering the brain to retrieve prior knowledge that is already known about a topic and use this information for further learning. Activation of prior knowledge is crucial for student learning.

Through semantic mapping, students have a visual representation of how words are related to one another. It has been found to be successful to students of all ages, and specifically helps visual learners in the classroom. This strategy can be used in a variety of ways, such as a pre or post learning strategy, a study skill technique or for general vocabulary development. Through the visual representation of words, students begin to discuss and validate prior understandings, and expand their own understanding of topics with semantic mapping.

Semantic mapping in vocabulary development is an instructional strategy used to initially active prior knowledge of a topic. This semantic mapping procedure prepares students to understand, assimilate, and evaluate information to be read. It also capitalizes on the use of work knowledge which has been shown to be the most important factor in reading composition (Heimlich & Pittelman, 1986).

Semantic Feature Analysis

Semantic feature analysis is a way of teaching significant concepts and vocabulary by developing a relationship chart. The Semantic Feature Analysis strategy is a technique that guides students through analyzing vocabulary by identifying key characteristics and comparing these characteristics with other known concepts. Through the use of a matrix grid, students are able to code a number of key vocabulary or concepts in terms of several important qualities (Bushel, 2001). After completing the strategy, students have a visual representation of how various concepts are alike or different.

Figure 3 demonstrates the use of the Semantic Feature Analysis in the classroom. This semantic feature analysis required students coding of each criteria within the matrix. A plus sign meant this word exhibits the feature, a minus sign meant the word did not exhibit this feature, and if students were unsure a question mark would be recorded within the specific matrix box. Teachers and students can then have open discussion of similarities and differences between terms for the category being analyzed (Buehl 1995).

Figure 3: Semantic Feature Analysis

SEMANTIC FEATURE ANALYSIS: GOVERNMENT OFFICIALS

Category / *People in Government* — **Features**	*is an elective office*	*is an appointive office*	*has term lengths*	*has limits on service*	*can be held by any legal voter*	*passes laws*	*vetoes laws*	*administers laws*	*declares laws unconstitutional*	*serves the entire United States*	*works within the United States*
President of United States	+	-	+	+	-	-	+	+	-	+	+
Governor of Wisconsin	+	-	+	-	+	-	+	+	-	-	+
U.S. Senator	+	-	+	-	-	+	-	-	-	?	+
Secretary of Defense	-	+	-	-	+	-	-	+	-	+	+
Supreme Court Justice	-	+	-	-	+	-	-	-	+	+	+
Ambassador to England	-	+	-	-	+	-	-	?	-	+	-
State Legislative Member	+	-	+	-	+	+	-	-	-	-	+

(Buehl, 1995)

There are several advantages to this strategy. Rather than recording short definitions, students analyze key vocabulary from their studies. Through their analysis, students will become aware of words within categories and develop an understanding of how words are similar and different. Throughout a unit of study, students have the ability to add and refine their matrix in order to adapt the instructional strategy to their own personal needs.

Graphic Organizers

Graphic organizers are two-dimensional visual arrays showing relationships among concepts. They are usually compared to the brain's natural storage of information into categories. When new knowledge is learned, it must be assimilated with existing prior knowledge. Students are engaged in higher level thinking skills through graphic organizers. Through graphic organizers, students develop relationships among concepts in an organized fashion. Graphic organizers can be targeted to meet the needs of vocabulary instruction, Monroe and Pendergrass (1997) combined a discussion model for developing understanding of new words with Concept of Definition, a graphic form with similar features. This adapted model is called the Frayer Model. (Monroe, 1998).

The Frayer Model

The Frayer Model is essentially a more sophisticated graphic organizer. The Frayer Model may be used for vocabulary instruction in any content area. It works especially well to develop an understanding of vocabulary terms in math and science. Through the four specific components of this graphic organizer, students are constructing a deeper understanding of what the concept entails. These components are noted as essential characteristics, nonessential characteristic, examples and non-examples. Figure 4 is an example of a Frayer Model. The Frayer Model is a technique that allows students to analyze characteristics of vocabulary terms that are being examined. Students develop a list of essential characteristics and non essential characteristics. Through this analysis they develop more examples of items with required uniqueness and non examples.

Figure 4: Frayer Model

Polygon

Essential Characteristics	Non-essential Characteristics
closed plane figure straight sides more than 2 sides 2-dimensional made of line segment	number of sides (must be higher than 2) number of angles equilateral (all sides same length) scalene (all sides different length) isosceles (at least 2 congruent sides)
Examples pentagon hexagon quadrilateral rectangle trapezoid square parallelogram heptagon triangle rhombus octagon	**Non-examples** circle cube cylinder sphere cone ray

Source: Cindy Penfram—Conway Middle School, Florida

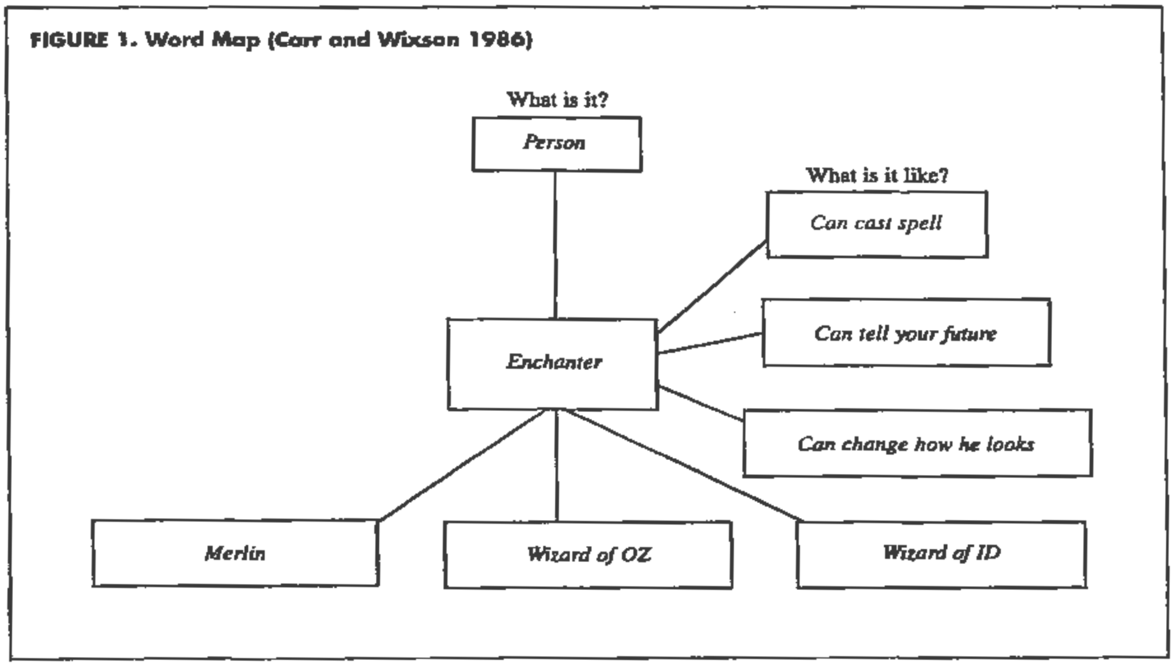
Concept Mapping

Concept mapping is a strategy that helps to enrich students understanding of a word or concept. Concept definition maps are graphic structures that focus students' attention on key components of a definition: the class or category, the properties or characteristics, and illustrations or examples. In the process of creating concept maps, students relate new information to more general concepts already held, develop fuller understandings of those general concepts, and recognize new relationships between concepts. Students engage in these activities by linking concepts to sub concepts, describing the relationships with propositions, and creating cross links (Royer & Royer, 2004). Concept maps can be used in classrooms for a variety of ways. Classroom teachers can use concept maps with students who benefit from a visual representation of information in order to display prior knowledge and integrate that knowledge with new learning. Through concept maps more complex concepts or issues can be explored and investigated in a visual and graphic way so that students can actually see the issues or factors of a given concept. More importantly, a concept map can demonstrate a misconception that may hinder further understanding or analysis students may discover this on their own through their analysis of new knowledge with previous learning, or it may be something the teacher uncovers for further instruction. Overall, concept mapping can be beneficial to many students who benefit from hands on, visual representations of their learning in graphic form.

Word Maps

Another strategy to use to aide in the retention of knowledge is word mapping. In this strategy, students can map out the meaning of words in order to enhance their understanding of the word. The Word Map technique (Schwartz & Raphael, 1985) is useful for helping students develop a general concept of 'definition." It makes them aware of the types of information that make up a definition and how that information is organized. A Word Map is a graphic representation of the definition of a word and focuses on three questions: What is it? What is it like? What are some examples? (Greenwood, 2002). Figure 5 Demonstrates how a word map helps students to develop their own definition of a word. It allows students to create their own meaning using context clues and their background knowledge.

Figure 5: Word Map



While this is a beneficial vocabulary development strategy, it is most beneficial in the area of reading. Students can use this strategy to analyze homophones and synonyms that they find in different contexts. It helps demonstrate the different meanings between words found in texts.

Summary

The development of mathematical vocabulary can not be ignored. Students more be provided adequate opportunities to learn this vocabulary in meaningful ways. Learners need experiences with constructing meaning from context as well as direct teaching strategies (Monroe & Orme, 2006) There are a variety of instruction strategies that target vocabulary instruction in mathematics. Students' understanding of mathematics is dependent on their knowledge of both mathematics as a language and the language used to teach mathematics. Empowering students in mathematics depends on teachers' helping students to make the connection between the language used to teach mathematics and their construction of mathematics knowledge (Miller, 1993. p. 311).It is crucial that educators use their profession knowledge in order to instruct using strategies that will be most beneficial to students in the classroom as all instructional methods have not been found to be valuable to all students. Furthermore, the literature demonstrates the need for educators to be trained in a variety of vocabulary building instructional techniques in order to ensure all students are receiving rigiorous vocabulary instruction throughout their educational experience.

Methodology

This research study investigated the question: Can direct vocabulary instruction increase student's background knowledge in math? The research primarily hoped to reinforce the benefits of direct vocabulary instruction during math in an elementary school classroom with students of diverse educational needs.

Participants

This study was in a fifth grade general education classroom in a suburban district around Rochester, NY. Among the classroom that was examined were students with Speech/Language Services and Academic Intervention Services. The classroom contains 26 students who had math instruction for seventy minutes a day, five days a week.

Materials

The teacher used the district adapted curriculum and lessons in order to drive instruction throughout both units of study. Learning standards and outcomes were also reviewed in order to align learning with required learning strands.

Procedure

Student achievement will be compared from two different Math Investigations units using direct vocabulary instruction and a unit without emphasis on vocabulary building strategies. Throughout lessons during the first unit of study students were given notes in order to develop an awareness of vocabulary words and procedures to solve problems throughout the unit. Students were given definitions of required vocabulary and examples of such but no direct vocabulary instruction techniques were used by teachers during instruction. Students used vocabulary as needed during lessons and activities. If a vocabulary term was needed but unknown, students would be prompted to retract their notes in order to find the necessary terms for discussion. The teacher noted the need for students to be readily reminded of vocabulary terms and the ongoing basis of prompting needed in order for students to use these words in instances where understandings of these terms are needed.

Throughout the second unit of study, notes were also given throughout lessons in addition to direct vocabulary instructional techniques such as the Frayer Model or concept mapping were used and referred to on an ongoing basis. Students were required to know and use these words readily and without prompting or assistance.

Data Collection

Data was collected on an ongoing basis through the classroom teacher's anecdotal notes, observations, student discussions and through student work samples and assessments.

Success will be demonstrated through student's ability to readily use and explain vocabulary term through speaking or in written language without assistance. Homework and assessment scores will be compared from both units in order to determine the ability to demonstrate a greater understanding of vocabulary from direct vocabulary instruction.

Results

The increase in student involvement and understanding of vocabulary increased tremendously throughout the 2nd unit of learning through qualitative data and quantitative data. Observations between students using vocabulary was readily noted and highlighted throughout the second unit of student. Student achievement and success increased dramatically in the later unit, Picturing Polygons. Most students had the ability to recall information and use vocabulary readily to express an understanding of concepts was done on an ongoing basis without prompting by the teacher as compared to the previous unit in which teacher prompting to use vocabulary in explanations of thinking was done on a frequent basis. Students were able to explain and extend knowledge in order to make connections with the world around them and prior math understandings and concepts. Students were also able to make connections between concepts throughout the Picturing Polygon unit, such as angles within polygons.

Throughout this unit, students were being assessed more frequently, about every other week, and therefore were storing information in their working vocabulary that they were using more readily throughout the unit. Vocabulary was grouped together and assessed in categories to make information more manageable.

Management of student behaviors throughout the unit was done minimally as students were engaged and much more excited about Picturing Polygons. They asked thought provoking questions that allowed them to clear up misconceptions in order to fully understand ideas and questions. During independent work periods students were working collaboratively in order to answer questions neighbors may have or help students as needed if educators were working with other students within the classroom. The engagement level and participation level was high throughout the extension of the unit.

Table 1 provides the data for end of the unit assessment in our mathematical thinking unit. More than half of students, 16n out of 26 in the classroom were not meeting standards (level 1 and 2) for this end of unit assessment.

Table 1: Student Results for initial unit, Mathematical Thinking

Mathematical Thinking- Grade 5	
Level 4- Exceeding Standards	4 Students
Level 3- Meeting Standards	6 Students
Level 2- Working Towards Standards	12 Students
Level 1- Not Meeting Standards	4 Students
	26 Students Total

It is important to note that several adjustments were made throughout this unit due to the emphasis put on information contained within the Picturing Polygon Unit in the New York State standards and strands. The questions and work students completed independently in this unit were predominantly taken directly from New York State publications, such as the *New York State Grade Five Sample Test* (2005) and the *2006 Grade Five New York State Mathematics Assessment*. These publications made for more authentic type questions from publications provided by New York State. These questions helped students make connections and have more valid practice rather than skill based questions.

Table 2 provides the data for end of the unit assessment in our Picturing Polygon unit. More than half of students, 20 total, in the classroom were meeting or exceeding standards (level 3 and 4) for the unit.

Table 2: Student Results for later unit, Polygon Unit

Picturing Polygon-Grade 5	
Level 4- Exceeding Standards	9 Students
Level 3- Meeting Standards	11 Students
Level 2- Working Towards Standards	5 Students
Level 1- Not Meeting Standards	1 Student
	26 Students Total

The success rate (level 3 or level 4, meeting or exceeding classroom standards) changed from 38% (Mathematical Thinking Unit) to 77% (Picturing Polygon Unit) with an overall increase of 39%.

Discussion and Conclusion

This paper hoped to demonstrate the need for vocabulary instruction on a daily basis. A high level of emphasis was not placed on vocabulary during the initial unit, Mathematical Thinking. This may have been due to the fact that this unit by design was an introduction and review of previous learning from the fourth grade curriculum. It touched on many areas that were to be expanded within the fifth grade curriculum but lacked the depth or time span needed for students to fully grasp concepts and develop a keen understanding. It was evident that a more in depth teaching and understanding of terminology and vocabulary was necessary when looking at the success rate of student achievement from this unit (38%).

On the other hand, in Picturing Polygons, vocabulary was placed at a high emphasis from the beginning. Initial classroom lessons were focused entirely on vocabulary. Without the solid foundation of vocabulary students would lack the necessary background knowledge to succeed in later lessons throughout the unit. This high emphasis was necessary as vocabulary is continually being added on and used as learning became more in-depth and sophisticated. Assessments were ongoing and done frequently in order to maintain a focus and ensure data is valid. End of unit assessments are complied of pieces of each assessment in order to assess the true understanding of variety of concepts. The stressors on vocabulary on this unit are successful as noted in the increase of 39% passing rate in students within the classroom.

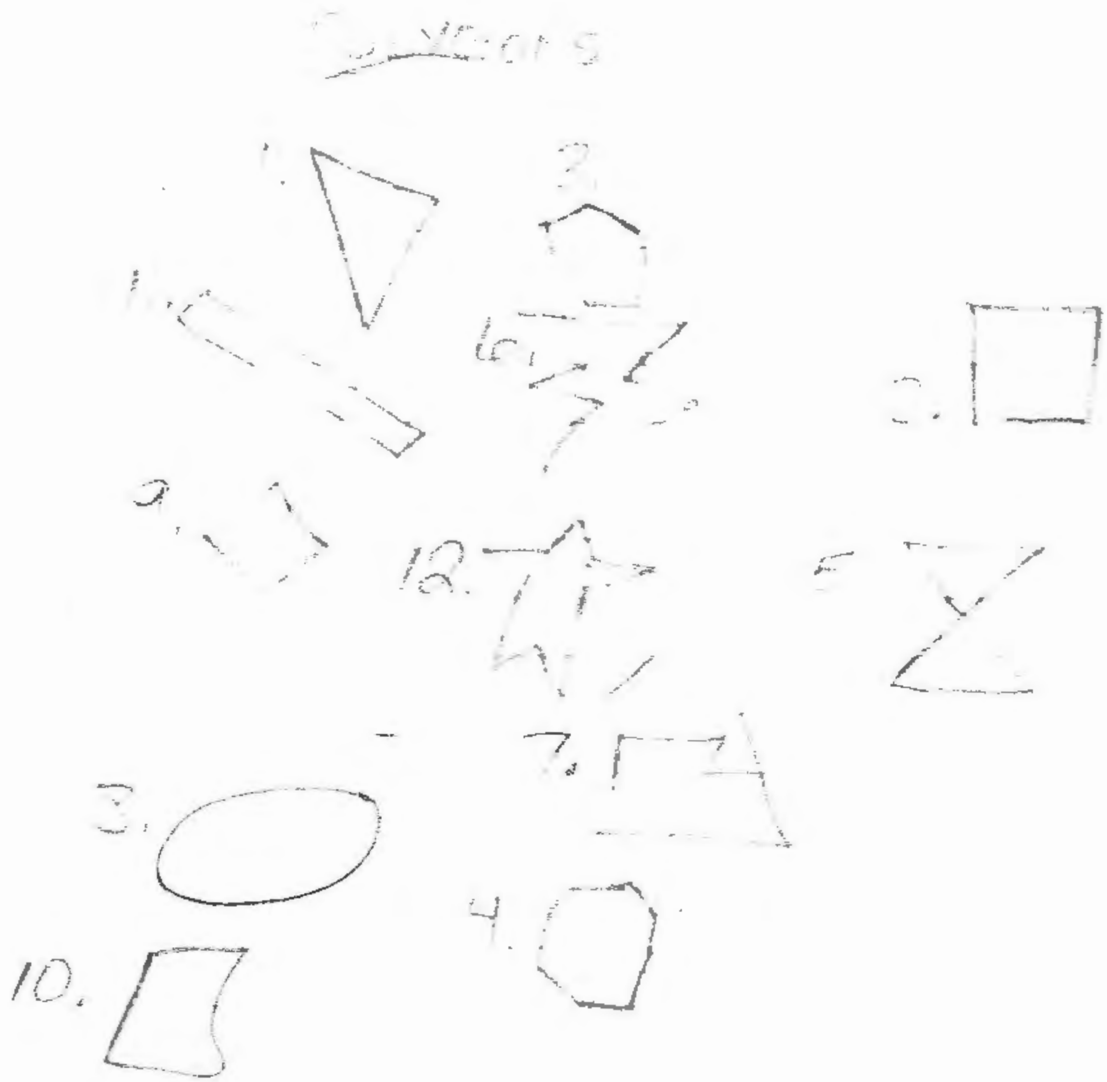
There were several adjustments that may be attributed to the increase of success level within the Picturing Polygon Unit. This success aligns with the literature that notes a loss in the ability to make real life connections between mathematical concepts and previously learned material (Schell, 1982). Throughout the Picturing Polygon unit, notes were given to children throughout that utilized the variety of instructional strategies that emphasis building vocabulary to build background knowledge in math. A variety of the techniques examined during the literature review were utilize throughout the teaching of this unit, such as The Frayer Model in order to help students construct meaning and make connections between mathematical concepts and the greater world. Students benefited from these theories and were able to make meaning of vocabulary words more so due to the unique models and how they allow students to itemize information. The Frayer Model was used in order to begin the unit and present students with a solid understanding of polygons. It helped students to categorize information and then concretely develop an understanding of the characteristics within polygons. Figure 6 is an example of student notes utilizing the Frayer Model instructional strategy. Students benefited from this instructional technique and were able to identify essential and non essential characteristics in order to develop a definition of a polygon.

Figure 6: Frayer Model from student notes

Another way vocabulary was emphasized was through inquiry based games within *Math Investigations* that support the understanding of vocabulary.

Figure 8 demonstrates the note page from a student during an inquiry lesson from *Math Investigations*. Students categorized shapes through game cards. Items within the circle follow the rules and characteristics of polygons. Items outside of the circle do not follow the rules of polygons.

Figure 8: Guess my Rule- Student Work Example



Students were also provided meaningful materials in order to develop an understanding of vocabulary. In Picturing Polygons students used manipulatives in order to discover connections between types of polygons. This hands-on approach allowed students tot construct meaning and use vocabulary in order to have mathematic discussions. When manipulatives were used within lessons students were using vocabulary to compare shapes and identify types of polygons. They enjoyed having concrete materials to use and refer to during cooperative group work.

The instruction and emphasis of vocabulary words throughout the unit helped provide scaffolds for students that prepared them for cooperative work in which they would need to use vocabulary words on their own. The emphasis of these words made students begin to use vocabulary on an ongoing without need prompting to do so.

Students realized the connection between the characteristics of polygons and angles they were learning about and their learning from early on in school. This made them realize their maturity and helped them see themselves as mathematicians themselves rather than students. They were confident in their work and were more willing to take risks in the classroom.

The different methods and strategies applied to note taking throughout the unit required students to apply background knowledge and vocabulary on an continual basis each day. This provided the supports necessary to develop an understanding and confidence of the knowledge students had in regards to geometry. Students in turn were participating more, asking relevant questions and taking more pride in their work.

Student achievement was at a higher rate when information was processed and presented in a variety of ways in order to make meaning to students. If achievement was lacking or if there was a deficit of knowledge, adjustments would be made in order to re-teach and evaluate what information needed to be re-taught. This unit contains vocabulary and concepts that is heavily weighed within the New York State Assessment so the time was well spent and necessary for student understanding and achievement. It provided that extra boost students needed in order to move forward with concepts and lessons.

In all, the Picturing Polygon Unit provides a more rigorous learning experience for students. Students learn to define, categorize and construct angles within polygons. Research data demonstrates the emphasis that educators should be putting on vocabulary within mathematics instruction. Educators must develop lessons that emphasize vocabulary in a variety of ways in order to develop an understanding of concepts in students. Without doing so, it in inevitable that students will maintain an understanding for a short period of time without retaining vital information that will provide a foundation for further more extensive concepts and learning. This lack of understanding will hinder their success as mathematicians in the greater world around us.

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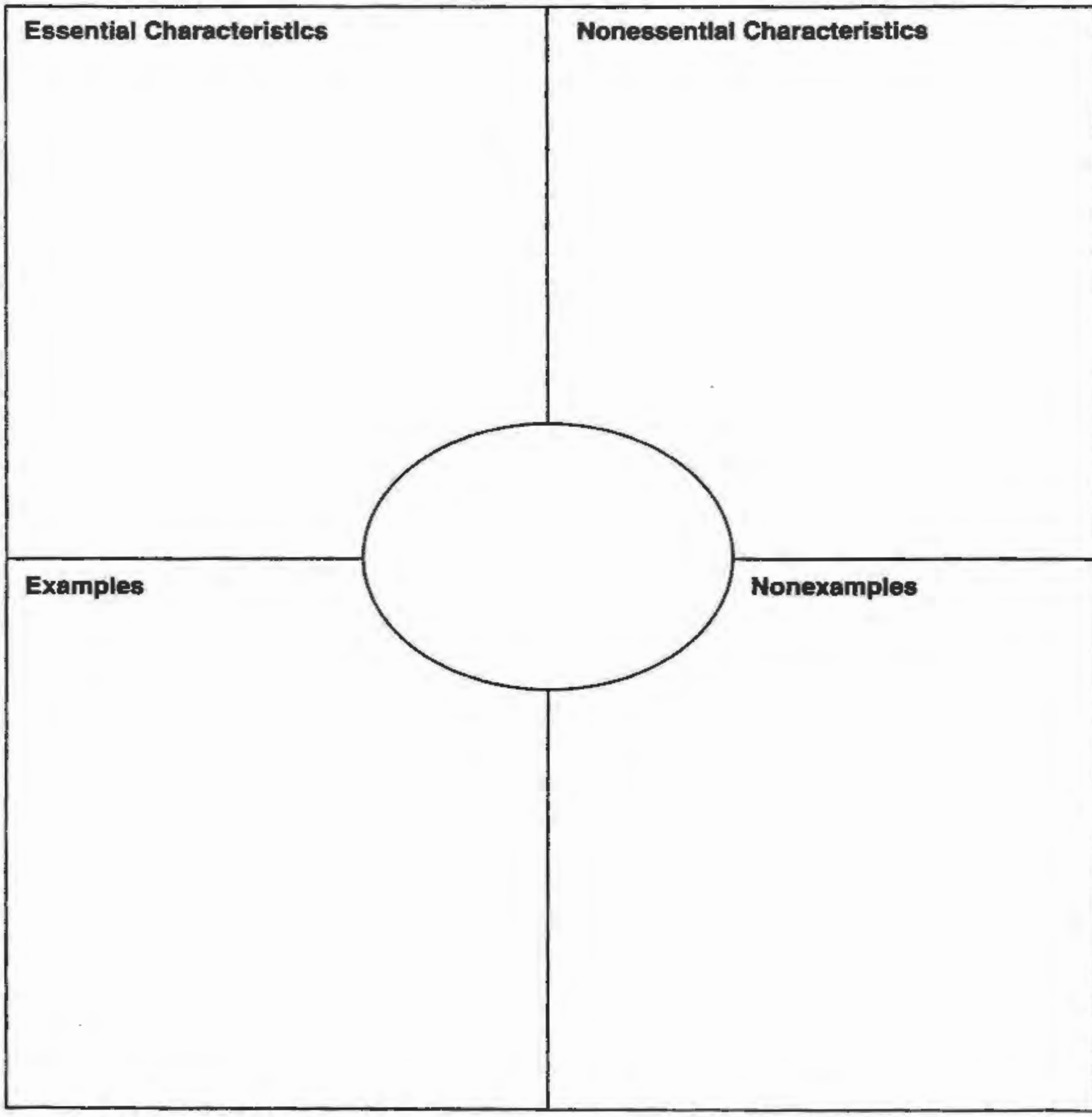
Appendix A

Frayer Model

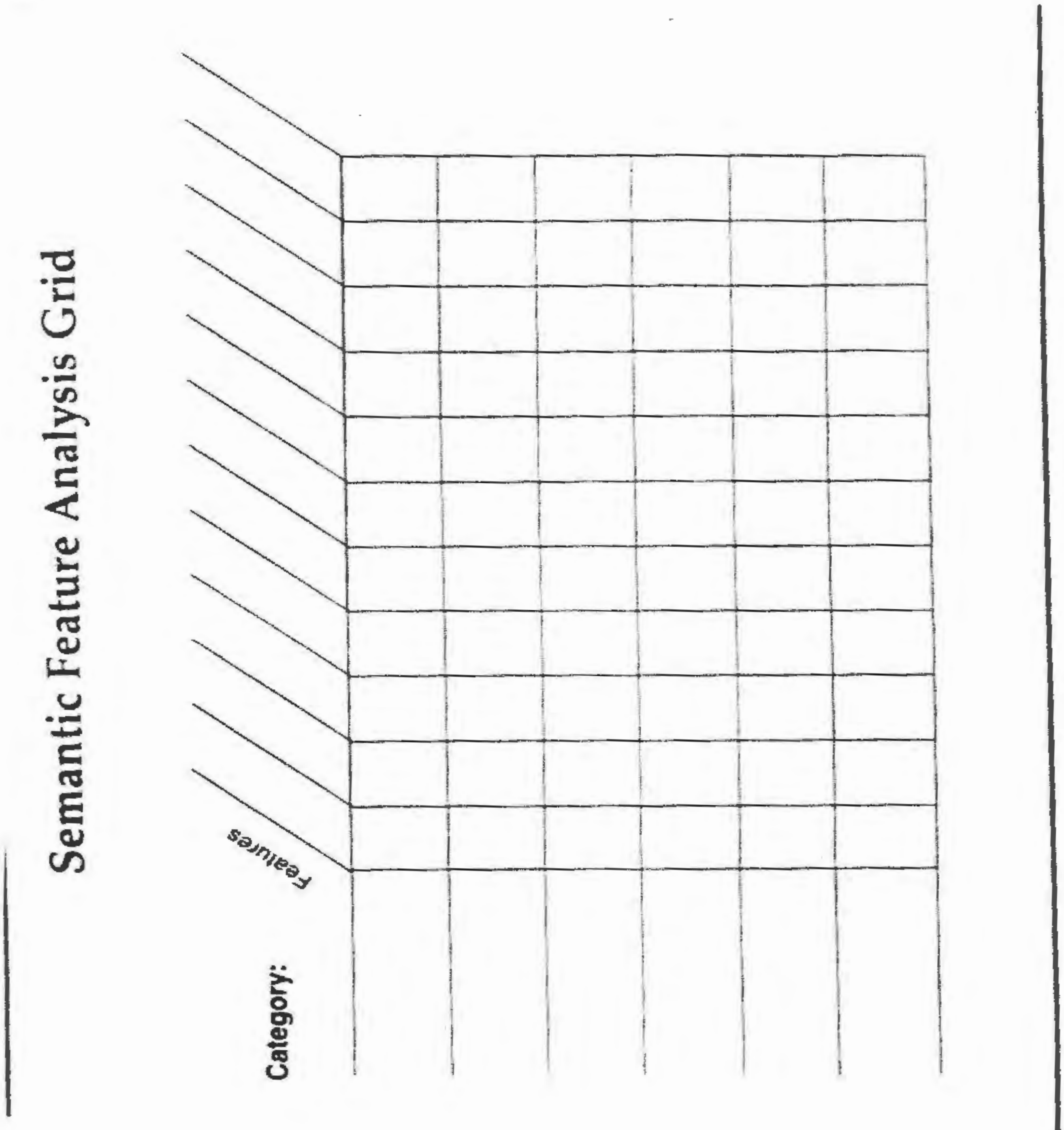
Frayer Model



(Frayer, Frederick, & Klausmeier, 1969)

Appendix B

Semantic Feature Analysis



Appendix C

Concept/Definition Map