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Effect of Directed Study of Mathematics Vocabulary on Standardized Mathematics Assessment Questions

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EFFECT OF DIRECTED STUDY OF MATHEMATICS VOCABULARY ON

STANDARDIZED MATHEMATICS ASSESSMENT QUESTIONS

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VITA

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ABSTRACT

The problems under investigation included (a) Did a directed study of mathematics vocabulary significantly affect student performance levels on standardized mathematical questions? and (b) Did the strategies used in this study significantly affect student performance levels on standardized mathematical questions? The population consisted of eighth-grade pre-algebra students from two different middle schools in southern Indiana. This quasi-experimental study was of a quantitative, repeated-measures design, using a population of approximately 140 eighth-grade students with a control sample of 37 and an experimental sample of 52. I performed a repeated measures ANCOVA to analyze scores from a mathematics vocabulary posttest for each participant, by the treatment and control groups, while controlling for student pretests scores. Results showed that after adjusting for pretest scores ($F = 20.12$, $p < 0.0001$), students who received intervention through a directed study of mathematical vocabulary had significantly higher posttest scores compared to the group who did not receive treatment. Students in the treatment group were required to keep a vocabulary journal, part of which was a self-rating of their understanding of each term. At the conclusion of the study, I assigned journal/understanding ratings for each term in the participants' journals. To decide if the journal/understanding scores were associated with pretest and posttest scores, I performed a Pearson's correlation analysis using the continuous variables of journal/understanding score and pretest and posttest scores. There was no significant correlation to the pretest scores for either the student self-rating journal/understanding scores ($r = -0.04$, $p = 0.756$) nor the

journal/understanding scores that I assigned(r = -0.04, p = 0.756). The results of the correlation analysis showed that the rating of students on their own journal/understanding (r = 0.23, p = 0.103) did not have any correlation with the posttest scores; however, the rating given by the teacher on the journal/understanding of the student was positively correlated with the posttest scores (r = 0.38, p = 0.005). Higher posttest scores were associated with higher journal/understanding scores, with a moderately positive correlation. School professionals such as teachers, administrators, and curriculum directors can assess and review the intervention done in this study and explore replicating or incorporating the approach in their curriculum. With the increase in test scores due to a directed study of mathematical vocabulary, school officials may consider this approach to increase the learning of students and as a result, increase their test scores on high-stakes examinations.

PREFACE

This dissertation is submitted for the degree of Doctor of Philosophy at Indiana State University in Terre Haute, Indiana. The research described herein was conducted under the supervision of Professor Susan Kiger, Ph.D., in the Department of Teaching and Learning at Indiana State University, between August 2016 and December 2016.

The research was conducted by me, a public middle school teacher for 44 years. The study took place in eighth grade pre-algebra classes in two rural, public middle schools in central Indiana. This study was designed to ascertain if the intervention employed to study mathematics vocabulary affected student scores on standardized mathematical questions and to add to the knowledgebase of vocabulary instruction and effective vocabulary practices in mathematics.

This dissertation should be of interest to mathematics educators, curriculum specialists, and administrators in educational settings.

ACKNOWLEDGMENTS

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DEDICATION

I dedicate this to my mother and father. To my father, who is no longer living, because he instilled in me the need to set goals in life and to work hard to achieve them. I miss you, Dad. To my mother who has loved me, encouraged me, and has been a shining example of a humble servant of God. I love you, Mom.

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THE LANGUAGE OF MATHEMATICS

Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it; without these, one wanders about in a dark labyrinth.

Galileo, The Assayer

CHAPTER 1

INTRODUCTION

The National Council of Teachers of Mathematics (NCTM) brought reading and writing in mathematics to the forefront in 1991 (Lappan, 1991) with the publication of a standards-based mathematics curriculum. Mathematics became more than just solving for the correct numerical answer. Mathematical training in which the student simply memorized facts and rules in order to do computational problems now included teaching for basic understanding of why these rules worked and became a prerequisite students needed to master so that problem solving could transpire. Along with the ability to solve a problem, communicating both orally and in writing also came to the forefront to be considered as important skills.

In April of 2014, influenced by Common Core and College and Career-Readiness Standards, Indiana's State Board of Education approved the adoption of new academic standards for language arts and mathematics (Indiana Academic Standards, 2015a, 2017c).

> They have been validated as college and career ready by the Indiana Education Roundtable, the Indiana Commission for Higher Education, the Indiana Department of Education, the Indiana State Board of Education, and the Indiana Center for Education and Career Innovation. This means that students who successfully master these objectives for what they should know and be able to do in Math and English/Language Arts disciplines by the time they graduate from high school will be ready to go directly

> into the workplace or a postsecondary educational opportunity without the need of remediation. (Indiana Academic Standards, 2017c, para. 1)

The Indiana Academic Standards for Grade 8 Mathematics clearly outline what students should know and be able to do in the area of eighth-grade mathematics. Students are required to demonstrate the acquisition of these skills and knowledge within classroom activities and assessments, along with the ability to apply what they have learned when taking the Indiana Statewide Testing for Educational Progress Plus (ISTEP+; Indiana Department of Education, 2015a, 2017c). Authors of the Indiana Academic Standards suggest that students who pass the ISTEP+ in language arts and mathematics have demonstrated that they are on the path to becoming college- and career-ready (Indiana Academic Standards, 2015a, 2017c). Passing or failing a high-stakes test such as ISTEP+, which is used as the culminating assessment to determine college or career preparedness, can have many potential consequences for students. These tests can determine academic opportunities, can affect how and where students are placed in school programs, and can even affect a child's self-esteem. Whether one agrees that the growth of a student can be assessed with a single, high-stakes, standardized test is not for discussion in this study. The question in this study is not whether students should be tested but rather how schools can improve student performance on the test.

The implementation of Indiana's new mathematics standards, based on the Common Core, has marshaled a new generation of assessment demands. According to Brenneman (2014), there are some major concerns regarding this new type of assessment. Among the concerns that Brenneman listed are (a) writing an assessment that measures depth of understanding instead of breadth, (b) designing performance tasks that challenge students to apply mathematical knowledge through multiple standards simultaneously, (c) expecting students to solve real-world problems, and (d) creating assessments that control cultural biases. Can "assessments be developed to accurately measure the problem-solving acumen now expected of students?" (Brenneman, 2014, para. 1).

With the beginning of Common Core-aligned testing, it is of interest to see how students perform and whether these new performance tasks will bring positive instructional changes to the classroom and to performances on standardized test questions. In this study, I examined whether a directed study of vocabulary in the classroom affected student performance on standardized mathematical questions.

Statement of the Problem

When a student reads mathematical text, he or she not only must recognize a word but also must have an understanding of the concepts underlying the word and possess the mathematical processes the word may require the student to know or perform (Burns, 2006). Riccomini, Smith, Hughes, and Fries (2015) emphasized this by stating,

> Specifically, in relationship to the language of mathematics, the ability to use words (i.e., vocabulary) to explain, justify, and otherwise communicate mathematically is important to the overall development of mathematical proficiency. In addition, research shows that language is a pivotal component of mathematics success (Seethaler, Fuchs, Star, & Bryant, 2011), and a student's general knowledge of mathematical vocabulary can predict mathematical performance (van der Walt, 2009). (p. 236)

Kenney, Hancewicz, Heuer, Metsisto, and Tuttle (2006) asserted that the language of mathematics consists of content and process. The content consists of nouns such as numbers, "measurements, shapes, spaces, functions, patterns, data, and arrangements," and verbs such as compute, identify, solve, and simplify represent actions that are performed during the processing of these mathematical objects (Kenney et al., 2006, p. 2). Thus, the research question of the study was "Does a directed study of mathematics vocabulary significantly affect student performance levels on standardized mathematical questions?"

The language of mathematics presents unique challenges for students in the classroom; for many students, it is analogous to learning a foreign language. "Parlez-vous geometry? Sprechen sie fractions?" (Burns, 2006, p. 41). Burns was inducted into the Educational Publishing Hall of Fame in 2010 by the Association of Educational Publishers; the author commented on the teaching of mathematics' unique vocabulary, stating,

> Math can sometimes seem like a strange language from a foreign land—one communicated in symbols, numbers, and geometric figures. And when we talk about mathematical concepts, even familiar, garden-variety words—such as *parallel, power, even, odd, multiply, difference, product, positive, and negative*—take on brand-new meanings. (Burns, 2006, p. 41)

Burns (2006) conveyed that even though studying the language of mathematics may be similar to studying a foreign language, the two are different in that when studying a foreign language, one is learning new words for describing thoughts, naming things, and asking questions. When learning the language of mathematics, the reason for learning it is so that one can communicate about mathematical ideas. Burns stated, "It's necessary first to acquire knowledge about the ideas that the mathematical language describes" (p. 42). Once a student has acquired this new knowledge, then he or she will have reason to use the language of mathematics to communicate these new ideas. Thus, it can be logically stated that in order to teach the language of mathematics to students, it is necessary to teach both ideas and vocabulary. Mathematical vocabulary and mathematical symbols are both fashioned by social conventions. Words and symbols are made up by society, whereas the mathematical ideas themselves are based on logic. For example, "knowing if a specific number is or isn't divisible by 2 calls for *mathematical knowledge* that is gained by synthesizing what is known about division, and connecting this understanding with what is known about patterns of numbers" (Burns, 2006, p. 42).

Students are "asked to explain and justify their solutions, which involves increased use of academic language—a particular challenge for English-learners and students with below grade-level literacy skills" (Heitin, 2014, para. 10). Low-income students are also at a disadvantage when mathematical language is used, making academic vocabulary an obstacle for many; as stated by Corson (1997), "Many learners from some sociocultural backgrounds do not get ready access to this vocabulary outside school, making its use inside schools doubly difficult" (p. 671). According to an analysis of 2013 federal data, "For the first time in at least 50 years, a majority of U.S. public school students come from low-income families" (Layton, 2013, para. 1). In the school where I conducted the current study, 52% of students are on free/reduced lunch, which is an indication of low income and poverty (Indiana Department of Education, 2017a).

The language of mathematics not only presents unique challenges for students in the classroom, it can challenge teachers as well. Part of the problem is that some teachers lack a solid knowledgebase for effective instructional strategies that promote understanding and accuracy of use of mathematical vocabulary and language. "The field of teacher preparation needs programs of research that specify methods to develop engaged knowledge of vocabulary instruction and improve teacher use of effective vocabulary practices" (Ely, Kennedy, Pullen, Williams, & Hirsch, 2014, p. 36). I designed this study to determine whether an intervention used to study vocabulary will affect student scores on standardized mathematical questions and to add to the knowledgebase of vocabulary instruction and effective vocabulary practices.

Purpose of the Study

The purpose of this study emanates from the overriding research question: "Does a directed study of mathematics vocabulary significantly affect student performance levels on standardized mathematical questions?" Because very little research has been done to determine if a direct study of vocabulary has a significant effect on student performance on high-stakes questions, I developed this study to add to the body of knowledge so that educators may make more informed curriculum decisions within their own academic setting.

Interventions for mathematics vocabulary lessons were created using guidelines from Marzano and Pickering's (2005) book, *Building Academic Vocabulary: Teacher's Manual*, and then used as part of the directed study of mathematics vocabulary for this study. I included vocabulary activities from Houghton Mifflin Harcourt's GO MATH Middle School Grade 8 (Burger, Dixon, Kanold, Larson, Leinwand, & Sandoval-Martinez, 2014) in the directed study to help introduce vocabulary words when beginning a new unit. Using pretests and posttests created through the Acuity Assessment System (2016), scores from students in both the control group (n = 37) and the experimental group (n = 52) were compared to determine if a directed study of mathematics vocabulary significantly affected student performance levels on questions such as those found on standardized mathematical tests.

Research Questions

In a recent study, Riccomini et al. (2015) established that understanding and comprehension of vocabulary in the language of mathematics is critical to student performance in the classroom and on high-stakes mathematical tests. The research questions that were studied were

1. Did a directed study of mathematics vocabulary significantly affect student performance levels on standardized mathematical questions?

2. Did the strategies used in this study significantly affect student performance levels on standardized mathematical questions?

Riccomini et al. stated that with the newly adopted Common Core State Standards for Mathematics, "Language development and more specifically vocabulary, are now new points of emphasis and important aspects for teachers to begin to address" (p. 236). Riccomini et al. continued to say,

> In an effort to improve students' overall mathematical performance, educators need to recognize the importance of, and use research-validated instructional methods to teach important mathematical vocabulary. It is important to recognize the many and varied difficulties that present challenges for students; finding instructional strategies and activities to help students overcome these difficulties is imperative. (p. 237)

Although a common belief with many teachers is that simply exposing students to new vocabulary words through rich context-specific interactions is the best way to teach vocabulary, Marzano and Pickering (2005) stated that many students will require more systematic and explicit instructional techniques and purposeful instructional activities to facilitate their learning.

Significance of the Study

Because very little research has been done to determine if a direct study of vocabulary has a significant effect on student performance on high-stakes questions on standardized tests, this study is needed to add to the body of knowledge so that teachers may make more informed operational decisions about the curriculum within their own classrooms. This study contributes to the knowledge base about teaching mathematical vocabulary by adding the specific interventions and the instructional strategies that were developed for this study, which improved student achievement on standardized test questions. Students who are unable to read and comprehend the language of mathematics are at a definite disadvantage in the classroom and when taking assessments. Capraro and Capraro (2006) asserted that “in today’s climate of high-stakes accountability and recent national legislation, it is important to examine the influence of language on mathematical performance” (p. 21). Kenney et al. (2006) posited the following reasons that make reading in mathematics so difficult:

1. Researchers have shown “that mathematics text contains more concepts per sentence and paragraph than any other type of text” (p. 11);
2. Writing in mathematical texts is very compact and contains words as well as symbols;
3. Sometimes information is located apart from the text, perhaps in a graph or picture somewhere on the page;
4. Reading from left to right does not necessarily apply when reading a mathematical text;
5. Students may also be confused by look-alike symbols, sound-alike words, poorly formatted graphics, or page layouts that are difficult to follow.

To summarize, in mathematics, vocabulary may be confusing because the words mean different things in mathematical and non-mathematical contexts because two different words sound the same, or because more than one word is used to describe the same concept. Symbols may be different representations used to describe the same process (e.g., $\times$, $\cdot$, and $*$ for multiplication). Graphic representation may be confusing because of formatting variations (e.g., bar graphs versus line graphs) or because the graphics are not consistently read in the same direction (Kenney et al., 2006, p. 7). Blachowicz and Fisher (2002) explained that vocabulary words are at the heart of the concepts being taught in any content area, and, through their understanding of new terms, students build a foundation that will enhance further and continuous knowledge of the new concepts. Blachowicz and Fisher stated that when a student is completing a mathematical exercise, the student has to refine and broaden his or her mathematical knowledge along with applying his or her ability to read and understand the information given in the problem. Fisher and Blachowicz (2013) cautioned that “the nature of math and science vocabulary suggests that we have to think differently about teaching vocabulary in these domains” (p. 47).

In order to cultivate long-term student success in mathematics, students must naturally progress from the less complex and concrete to more complex thinking and difficult skills, which requires further mastery of vocabulary and the use of “specific instructional strategies supported by research” (Riccomini et al., 2015, p. 240). The first step was to study the language of mathematics and its vocabulary while teaching mathematics in a context that had meaning and was authentic for the learners. Riccomini et al. (2015) paraphrased Manzo, Manzo, and Thomas (2006) that in order to “maximize and facilitate improved understanding of essential vocabulary for students” (p. 239), it is important that a systematic plan is developed and used for teaching vocabulary throughout the year.

In this study, I provided the experimental group of students with a working knowledge of mathematical vocabulary through the use of planned interventions and instructional strategies. This was done within the lived experience of the classroom setting over the timeframe of the study, rather than an outside researcher having brief interventions throughout the length of the study. Students in the experimental group were also required to keep a vocabulary journal throughout the study. I then compared the results of standardized test questions for the experimental group to the results of students in the control group, who did not participate in this directed study of mathematics vocabulary. The data collected from and analyzed in this study contributed to and extended the knowledge base of the study of mathematics vocabulary by determining whether the specific planned interventions and instructional strategies affected achievement on standardized questions.

Theoretical Framework

I chose constructivism as the lens through which to review and support the creation and implementation of this directed study of mathematics vocabulary. Colburn (2000) stated that "people often see the teaching community as faddish—every year a different approach is 'in'" (p. 9). He discussed that individualized instruction, cooperative learning, discovery learning, inquiry-based learning, and discovery-based learning can all be seen through the concept of constructivism. "The strength of constructivism is that it unifies trendy teaching strategies. Many so-called fads in education turn out to have a firm, research-supported foundation in constructivist learning theory asserted that constructivism has multiple meanings in education circles" (Colburn, 2000, p. 9). Colburn described, "It refers to a philosophical view about the nature of reality and perception, is a theory about how people learn, and more and more often represents an array of teaching strategies" (p. 11). Brooks and Brooks (1999) stated, "As long as there were people asking each other questions, we have had constructivist classrooms. Constructivism, in the study of learning, is about how we all make sense of our world, and that really hasn't changed" (p. 27). Wilson (2012) identified the basic precepts of constructivism, based on the ideas of Dewey (1916/2009) and Vygotsky (1962) and Piaget's (1970) work in developmental psychology, as follows: students learn by doing, students bring prior knowledge to a learning situation, and students thereby construct new ideas and knowledge. In the interventions created for the directed study of mathematics for this study, teachers asked the students directed questions designed to guide and question their thinking. Learning was active as opposed to passive and was a process where knowledge was constructed, not merely acquired. Vocabulary knowledge was constructed based on personal experiences and creating and testing hypotheses while interpreting newly discoved ideas based on their own personal experiences and cultural factors.

Jonassen (1994) proposed that there are eight characteristics underlying constructivist learning environments:

1. Provide multiple representations of reality;
2. Represent real-world complexity and avoid oversimplification;
3. Emphasize knowledge construction as opposed to knowledge reproduction;
4. Provide real-world settings;
5. Encourage thoughtful reflection on experience;
6. Enable “content-and context- dependent knowledge construction” (p. 35);
7. Support “collaborative construction of knowledge through social negotiation, not completion among learners for recognition” (p. 35).

In Chapter 2, I applied the works of various theorists in detail to support the interventions for the directed study of mathematics vocabulary in this study. I paid special attention to Vygotsky’s (1962) zone of proximal development (ZPD) model, which contends that students can rely on assistance from adults or peers who are more advanced to help students master ideas and concepts that they cannot comprehend on their own (as cited in Steele, 1999). Using intersubjectivity, two or more participants may arrive at a shared understanding by adjusting to each other’s perspectives and therefore create a common ground for communication (Steele, 1999). Classroom methods employing scaffolding and guided participation facilitated interactions between the learners, subject matter experts, and the vocabulary being studied. Building mathematical vocabulary through daily mathematics instruction that emphasizes Marzano’s “six general recommendations is important and essential for many students especially struggling students and students with disabilities" (as cited in Riccomini et al., 2015, p. 240).

Definitions of Terms

Terms used throughout the conveyance of the study are identified as follows:

Acuity Assessment System. I used the Acuity Assessment System (2016) to create the pre- and posttests focusing on mathematics vocabulary. Acuity tests, which can be online or print exams in math and English, were created by CTB-McGraw Hill and educators having access through their educational institutions have access to the test question database and may create their own exams. Acuity tests are designed to aid school districts in tracking student progress toward passing ISTEP+ (Acuity Assessment System, 2016). Schools administer Acuity, sometimes multiple times per year, and use the scores to predict how their students will score on ISTEP+, to identify students who may need extra help, or to regroup students with classmates at the same skill level in an effort to tailor instruction in a way that will raise their scores (IDOE, 2015b). In the case of this study, I created pre- and posttests using the Acuity Assessment System, which offers "custom test building and item authoring capabilities, access to standards-based item banks, and over 2,000 Common Core-aligned instructional resources" (McGraw Hill Education, n.d., para. 4).

Directed study. In general, a directed study is a course of study that is supervised and controlled by a specialist in the subject. The guidelines for creating a directed study of vocabulary from Marzano and Pickering's (2005) book, *Building Academic Vocabulary: Teacher's Manual*, served as a framework for creating a directed study of mathematics vocabulary for this study. This book served as a model for designing, preparing, presenting, dealing with, and managing several organized steps, procedures, and techniques for a directed study of eighth-grade mathematics vocabulary and included the following elements:

Step 1: The teacher provides a description, explanation, or example of the new term.

Step 2: Students restate the description, explanation, or example in their own words.

Step 3: Students construct a picture, symbol, or graphic representing the term or phrase.

Step 4: Engage students periodically in activities that help them add to their knowledge of the terms in their notebooks.

Step 5: Ask students periodically to discuss the terms with one another.

Step 6: Involve students periodically in games that allow them to play with the terms.

High-stakes test. Finding a definition for high-stakes testing is difficult. There is much discussion about its pros and cons and debate over their accuracy and use in decision-making. The Education Alliance at Brown University says this about high-stakes testing,

> High-stakes tests are tests used to make important decisions about students. These include whether students should be promoted, allowed to graduate, or admitted to programs. High-stakes assessments are considered a natural outcome of the standards movement in the U.S. The declared purpose of the standards movement is to make students, teachers, and administrators responsible for a high standard of teaching and learning (Heubert, 2000). High-stakes tests are designed to measure whether or not content and performance standards established by the state have been achieved. (The Education Alliance of Brown University, n.d. para. 1)

Participants in this study will eventually be given the Indiana Statewide Testing for Educational Progress-Plus (ISTEP+) as required by Indiana law in April of 2017. Although this test is not part of this study, districts, schools, administrators, and teachers are held accountable for the students' performances. All are rated based on the scores from a single test, and students may not be able to be placed in certain programs or receive a diploma if satisfactory scores are not achieved.

Official mathematical language (OML). According to Herbel-Eisnemann (2002), Official mathematical language (OML) is language that is "part of the mathematical register and would be recognized by anyone in the mathematical community" (p. 102). In lieu of using student- or teacher-generated language in the classroom such as the "top number of a fraction" or the "bottom number of a fraction," the teacher would require the students to use "numerator" and "denominator" respectively. By requiring the use of OML in the classroom, students learn the proper vocabulary for each term.

Traditional educational setting. In this study, a traditional educational setting refers to a classroom where the delivery of instruction to classes of students is controlled by the teacher and students are the receivers of information. "Traditional schools generally stress basic educational practices and expect mastery of academic learning in the core subjects of math, reading, writing, science and social studies" (Huson, n.d., para. 3).

Delimitations

This study took place in eighth-grade pre-algebra classrooms only. One teacher instructed the treatment group using a directed study of vocabulary as described in this document. This group attended a seventh- and eighth-grade middle school in a rural community in southern Indiana. Students from the control group attended a middle school for Grades 6 through 8 approximately 30 miles from the experimental group's school. All students in the control group had the same teacher at the control group school. Subjects included special education and regular education students. The study did not include the academically advanced students at either school, as they were taking Algebra I for high school credit. I used the same treatment for all subjects in the experimental group. The teacher in the control group applied the same teaching methods for all of her students in order to reduce any variability in instruction.

Limitations

The population for this study was limited to students from two rural schools in southern Indiana located approximately 32 miles apart. Participants were both male and female adolescents ranging in age from 13 to 15 years. Participants were in eighth-grade pre-algebra classes and had varying degrees of mathematical ability. The process for selecting students for pre-algebra classes was the same for both schools. Students taking eighth-grade Algebra I were removed from the pool of eighth graders, and the remaining students, including special education students, made the pool from which the guidance counselors created the pre-algebra classes at each school. Class sizes ranged in number from 14 to 30 students per class. All participants were required to obtain written parental permission and had to complete a personal assent form to participate in the study. The length of the study was limited to a single semester.

Conclusion

Because very little research has been done to determine if a direct study of vocabulary has a significant effect on student performance on high-stakes questions on standardized tests, this study is needed to add to the body of knowledge so that teachers may make more informed operational decisions about the curriculum within their own classrooms. Although a common belief with many teachers is that simply exposing students to new vocabulary words through rich context-specific interactions is the best way to teach vocabulary, Marzano and Pickering (2005) stated that many students will require more systematic and explicit instructional techniques and purposeful instructional activities to facilitate their learning. The guidelines for creating a directed study of vocabulary from Marzano and Pickering's (2005) book, *Building Academic Vocabulary: Teacher's Manual*, served as a framework for creating a directed study of mathematics vocabulary for this study, and are listed in the definition of terms under directed study. This book served as a model for designing, preparing, presenting, dealing with, and managing several organized steps, procedures, and techniques for a directed study of eighth-grade mathematics vocabulary. I used the data collected and analyzed from this study to contribute to and extend the knowledge base of the study of mathematics vocabulary and determine whether the specific planned interventions and instructional strategies can affect achievement on standardized questions.

CHAPTER 2

LITERATURE REVIEW

The purpose of this study was to determine if there is a significant effect from a directed study of mathematics vocabulary on high-stakes test performance for eighth-grade students enrolled in pre-algebra in a rural school in southern Indiana. In this study, I attempted to determine if a directed study of mathematics vocabulary significantly affects student performance levels on standardized mathematical questions. I also attempted to determine if particular instructional strategies and methods affected performance. The following is offered to contextualize the knowledgebase of theory and practice used to undergird the creation of my intervention for my study population, and through which my findings were considered.

In this chapter, I reviewed the literature to provide background on the notions that (a) the language of mathematics poses unique problems for students, (b) there are proven strategies that can help students with these problems, (c) students' knowledge of a topic is often encapsulated in relevant terms they know related to the topic, and (d) the learning of new mathematics vocabulary must include an understanding of the underlying concepts associated with each new mathematical term. I included evidence of the importance of studying vocabulary in the content areas, especially math. A discussion of theory that supports how and why the study of vocabulary should take place demonstrates why certain strategies were chosen for the directed study of vocabulary in this research. Finally, I presented the six steps presented by Marzano and Pickering (2005) for the intervention used in this research.

The Language of Mathematics

The language of mathematics is unique. It is similar to a second language for many students, since most often it is not spoken at home but is used almost exclusively in an educational environment (Thompson & Rubenstein, 2000). The language of mathematics consists of specialized words, symbols, expressions, and words that have multiple meanings (Adams, Thangata, & King, 2005). In addition, because their root words are often Greek or Latin, mathematical terms frequently sound like they are from another language as well. Since many students cannot speak the OML they are therefore unable to communicate mathematically, construct meaning, share, or expand ideas in the mathematics classroom and on assessments (Herbel-Eisenmann, 2002). According to Jones, Hopper, and Franz (2008), much of the difficulty students experience in the mathematics classroom and on standardized questions may simply be because they do not have a mastery of mathematics vocabulary. "Students can clearly comprehend that mathematics is a powerful tool, but many have difficulty comprehending mathematics as a language" (Jones et al., 2008, p. 307). Sometimes the mathematics classroom is much like attending a class in which a foreign language one does not speak is being used. "To understand any passage, whether in mathematical or any other language, the reader must be able to translate the text" (Jones et al., 2008, p. 310). Entering into common classroom discourse would be extremely difficult. It follows that scoring well on assessments would be almost impossible if one could not read, write, and understand the language. In order to understand any passage, no matter what discipline, the reader must be able to define the words and successfully decode the information (Jones et al., 2008). Adams (2003) found that "a student's ability to recognize and employ the formal definition is key to understanding and applying concepts when reading mathematical text" (p. 787). Ultimately, the inability to speak and understand OML may affect student performance on high-stakes questions.

Vocabulary in the Content Areas

There have been several studies about the nature of vocabulary study in general. Harmon, Hedrick, and Wood (2005) noted the following:

> Vocabulary knowledge is closely linked to the difficulties many students experience in handling the demands of content textbooks. . . . [Teachers] would no doubt agree that a critical aspect of students' difficulty in understanding texts in their content area would be a lack of sufficient vocabulary knowledge. . . . The literature suggests that success in supporting vocabulary development in the content areas must consider students as word learners, the nature of content vocabulary, and the special features of effective vocabulary instruction. (p. 264)

Allen (1999) cited studies on vocabulary research that gave evidence that direct vocabulary instruction should take place in all content areas. Direct vocabulary instruction supported the learning of new concepts, deeper understanding of these concepts, and more productive communication. Blachowicz and Fisher (2002) stated that research and practice both supported the value of learning vocabulary in all content areas, in achieving the broader goal of acquiring content knowledge, and communicating within a discipline.

Vocabulary in Mathematics

At the time of this writing, I located no studies investigating the effects of a directed study of mathematics vocabulary on high-stakes test performance in the United States. I was able to locate a paper from Great Britain that proposed a framework to begin an analysis, review the literature, and raise more focused questions concerning the vocabulary and language usage on high-stakes tests in England and Wales. Shorrocks-Taylor and Hargreaves (1999) wrote, "The wording of the questions and interpretation of the response become vital and can influence the validity and reliability of the whole enterprise" (p. 4). "The possibilities for misinterpretation are many, especially if a child is reading text (such as test questions) in a [*sic*] unsupported way and in stressful conditions" (Shorrocks-Taylor and Hargreaves, 1999, p. 9).

Murray (2004) based her classroom instruction on "a record of research reaching as far back as 1944 that indicates a clear connection between vocabulary development and success in mathematics" (p. 4). Research from a broad spectrum of resources promoted the need for the study of mathematics vocabulary across all grade levels and even into college. I discovered that the study of mathematics vocabulary contributes both to student discourse in the classroom and to improved mathematics classroom performance.

In order for a direct study of vocabulary to be effective, the following methods and topics should be addressed when mathematics vocabulary is taught in the classroom. Thus, pulling from the work of Adams et al. (2005), Herbel-Eisenmann (2002), Murray (2004), and Thompson and Rubenstein (2000, 2007), a summation of five major points as illustrated in the following list further directed my literature review.

1. Etymology and history of mathematical words;
2. Confusion generated by mathematical terms having different meanings in the math classroom as compared to "everyday" usage;
3. Students learning definitions need to understand the concepts underlying the definitions;
4. Importance of students using multiple representations such as charts, graphs, tables, equations, problems in context, drawings, diagrams, and graphic organizers (Herbel-Eisenmann, 2002);
5. Need to teach the unique language of mathematics as if it was a foreign language (Herbel-Eisenmann, 2002; Thompson & Rubenstein, 2000).

The proceeding addresses each listed area in detail.

Etymology and History

Studying the etymology of mathematical vocabulary can give students a rich background in Latin and Greek root words that can be applied to vocabulary in other disciplines, serving as bridges to words in all content areas. The roots help to make connections to other words and their meanings. Many of the words used in mathematics evolved from life in ancient times. In the ancient Mediterranean, there was a practice of hanging a weight to construct a right angle to the horizon. The root word pend, meaning to hang, is shared by the words perpendicular, suspend, and pendulum (Rubenstein, 2000). With information about the root word, students would be able to construct a mental picture of the word perpendicular and share ideas about the uses of the words suspend and pendulum (Rubenstein, 2000). Rubenstein (2000) provided a table of roots, meanings, related words, and teaching notes for middle school vocabulary, algebra, geometry, and the study of data.

Rubenstein (2000) also posited that the roots of the names of some of the branches of mathematics can be used initially to pique the students' curiosity about word origins. The word *algebra*, meaning reunion of broken parts, comes from the title of a text, *Hasab Al-Jabr w'Al-Muqabalah*, written by an Arabic mathematician named Muhammad ibn Musa al-Khowarizmi (Rubenstein, 2000). Often, when an equation is solved in algebra, such as $2x + 3 = 4x - 5$, the first step is to "reunite" the variables. They have been broken apart and need to be put back together.

It is believed the word *geometria* was used by the Egyptians for surveying flooded lands on the Nile River, then was later passed on to the Greeks (Rubenstein, 2000). Geometry contains the root *geo*, meaning earth, and *metron*, meaning measure. "Calculus comes from the Latin word *calx*, meaning limestone . . . In ancient Rome . . . people used marbles or other pebbles (in

Latin, calculi) to count and to reckon, a process that led to our English word calculate" (Rubenstein, 2000, p. 2).

Another example of word origins lending meaning to words are the words *complement* of an angle, which is defined as the amount of degrees needed to equal 90 and its sound-alike *compliment,* which means describing something nice about a person. Both words were derived from a root word meaning to fill. The complement of a 30 degree angle is 60 degrees, because one would have to fill up the right angle with 60 to complete it, whereas a compliment makes someone feel fulfilled if one says something nice about them. As illustrated in the preceding examples, exposing the origins and meanings of Greek and Latin root words as a part of the directed study of mathematics vocabulary may help students make important connections that support retention in working and long-term memory.

Reasons for Student Confusion

In all content areas, students experience confusion with vocabulary meanings when words sound alike but have different meanings. Sound-alike words are found in everyday English as well as in mathematics, with their own mathematical meaning or in science with a scientific meaning. Sound-alike words can be *homophones,* defined in the Merriam-Webster Dictionary (https://www.merriam-webster.com/dictionary/homophone?utm_campaign=sd&utm_medium=serp&utm_source=jsonld) as one of two or more words pronounced alike but different in meaning, derivation or spelling, such as *weigh* and *way*. Or they can be *homonyms*, defined as one of two or more words spelled and pronounced alike but different in meaning such as *matter*—something that takes up space or a topic of concern. What is most helpful to students is to say the words clearly, "acknowledge that other words sound the same, identify those other words, say and spell each, define them, and use each in context" (Rubenstein, 2007, p. 205).

Everyday Words

As the etymologies of mathematical terms are learned, it is sometimes wise to include related English words because they can help students' understanding, while remembering that the degree of helpfulness will depend on the students' background knowledge. Adams et al. (2005) provided excellent examples in their article, "Weigh to Go!" Some of their examples include *volume, scale, product, point, odd, base, prime, average, power, and edge*. Each of these terms has a specific mathematical meaning but is also used in everyday English. The authors gave an example of an activity that helped students understand the mathematical term edge. The class was taken outside and asked to stand on the edge of the sidewalk. Then the teacher showed the class a three-dimensional solid, a cube, and asked them to picture themselves standing on the edge of the cube. This activity gives students an experience in the real world that they can connect to the term edge. The word similar describes things that are alike in some way. In everyday usage, all rectangles are similar. In mathematics, figures are similar if they have the same shape, all corresponding linear measures are proportional, and all corresponding angles are congruent. Mathematically, therefore, all rectangles are not similar. Educators need to be aware and address the fact that when they use one of these words in the mathematics classroom, the student may or may not be thinking of the mathematical meaning. This is especially true for non-native speakers of English.

Underlying Concepts

Renne (2004) asked her fourth-grade students, "Is a rectangle a square?" (Not the usual question, "Is a square a rectangle?") Although her students could easily identify a variety of two-dimensional shapes, they were "unable to use mathematical terms and concepts to describe the shapes" (Renne, 2004, p. 258). Her class had just been working with the geometric concepts of parallel, identifying angles, and congruency, but students were incapable of applying these ideas to compare shapes. They knew the definitions and could identify them but lacked the concepts underlying the definitions. Renne decided that connections between the vocabulary and the concepts needed to be established. She then went back to the concepts of congruency, right angles, and parallel within the context of discussing and characterizing basic geometric shapes. It is also important to emphasize Renne mentioned that having this discussion with her class was not enough for every student to understand the concept fully. For students to fully develop an understanding of this or any other concept, the teacher must remember that "building conceptual knowledge requires time and multiple experiences so that students can expand, apply, and refine appropriate and accurate vocabulary in various contexts" (Renne, 2004, p. 262).

Students' Need for Multiple Representations

Miura (2001) wrote about the influence of language on mathematical representations. This author related that students' understanding and solving of mathematics problems are generally affected by two types of representations. First, there are external instructional representations such as examples, models, and definitions. These may be shared with the teacher and with classmates. See Table 1 for a list of instructional representations.

Second, cognitive representations are constructed by students as they develop an understanding of a concept or try to solve a problem. These are internal and may or may not be shared with others. Both types of representations are influenced by cultural factors, language, and making connections to background knowledge. Hands-on activities, real-world applications, and the use of mathematical manipulatives must be provided to students to give them opportunities where they can use both types of representations to deepen their conceptual understanding of math vocabulary.

Table 1

Instructional Representations

Device	Use
Diagram	Information can be displayed in a spatial layout using visuals and student-drawn pictures that represent the problem. A diagram can help the student break down the parts of the problem and guide them toward a solution.
Table	Tables organize information in a problem in a shorthand method that helps the student efficiently compare quantities.
Charts & Graphs	Charts and graphs can help students show and discover patterns that will allow them to solve a math problem.
Examples	Teachers commonly provide examples, then model for students how the problem should be solved. Another way to use examples is to have students create their own examples to demonstrate they understand the underlying concepts.

Mathematics as a Language

When people discuss the language of mathematics, they are implying that it has much in common with different languages. Usiskin (1996), an expert in mathematics education, discussed how mathematics has many characteristics of a language and the teaching and learning of different languages. Mathematics is like other languages in that it is both oral and written and can be either formal or informal. Communication of ideas is a major purpose and allows the user to describe concepts, helping them to shape these concepts in his or her own mind. Symbolism plays a large part in mathematics and should be embraced rather than feared, which is often difficult to teach to first-year algebra students. Usiskin asked, “If mathematics is a language like English, then why is it so much harder to learn?” (Usiskin, 1996, p. 232). “Mathematics texts are challenging to read because they have more concepts per word, per sentence, and per paragraph than any other area” (Schell, 1982, p. 544). With few exceptions, the language of mathematics is not spoken at home but only in an educational setting. Usiskin stated that research confirms that "if the oral language is not learned before a certain age, then physical limitations may develop that make it difficult or even impossible to learn the language" (p. 238). The implications of this statement suggest teachers may be depriving some students by not teaching certain concepts early enough.

Former NCTM president Mary Lindquist (1996) commented, "If we consider that mathematics is a language and that this language is best learned in a community of other learners, then it is easy to understand why there is a communication standard" (p. 2). Part of communication is listening. Students need to be given a chance to use oral and written language in the mathematics classroom. "As in foreign-language acquisition, immersion in language usage is necessary to develop fluency" (Thompson & Rubenstein, 2000, p. 571). When learning a different language, attention is paid to pronunciations and proper usage of the words. Students must be given opportunities to talk about mathematics using the language of mathematics. Teachers should listen as students communicate in groups while evaluating if students are using terms in their proper context and assuring they are exhibiting understanding.

Constructivism and Mathematics Vocabulary

According to Miller (1993), a key component to understanding mathematics is learning the vocabulary. Many educators agree with Miller that "without an understanding of the vocabulary that is used routinely in mathematics instruction, textbooks, and word problems, students are handicapped in their efforts to learn mathematics" (p. 312). Because of the high incidence of unfamiliar vocabulary in mathematics (Schell, 1982), teaching unknown words becomes central to mathematical literacy. Xuan and Perkins (2013) referred to Bruner's constructivist theory, citing that the curriculum has a direct impact on learning. They also referenced that Bruner postulated that as a curriculum develops, it "should revisit the basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them" (p. 8). In my directed study of mathematics vocabulary, it was planned that students would continually revisit vocabulary words, adding to their knowledge of the word with each additional visit. Playing games with the words should also have an impact on student learning.

Marzano and Pickering (2005) stated, "The influence of academic background knowledge on academic achievement is fully and firmly documented in research" (p. 71). Ellerton and Clements (as cited in Miller, 1993) believed that "when someone actively links aspects of his or her physical and social environments with certain numerical, spatial, and logical concepts, a feeling of 'ownership' is often generated" (p. 313). Constructivism supports the idea that people build knowledge by integrating new experiences with prior knowledge. Hung (2002) stated that Dewey believed that,

> the role of learning is to bridge the inherent tension between known and unknown in a dialectical or transactional process. Ideas can be the main instruments of that activity. Ideas, or rather the metaphoric-psychological signs that instantiate ideas, connect the old and the new. (p. 197)

Dewey (1916/2009) also added a social context to learning new words by connecting background knowledge:

> To formulate the significance of an experience a man must take into conscious account the experiences of others. He must try to find a standpoint which includes the experience of others as well as his own. Otherwise his communication cannot be understood. He talks a language which no one else knows. While literary art furnishes the supreme successes in stating of experiences so that they are vitally significant to others, the vocabulary of science is designed, in another fashion, to express the meaning of experienced things in symbols which any one will know who studies the science. (p. 388)

In order for students to hear about, think about, and talk about mathematical ideas, they must have words to express their ideas and findings.

Without learning mathematical vocabulary, students will be unable to communicate mathematically. Baumann and Kame'enui (2012) suggested the following constructivist elements when teaching vocabulary:

1. Instead of explicitly teaching students everything about a word, give them opportunities to construct their own knowledge;
2. Motivate the students with engaging material;
3. Provide collaborative discussion and strategies in which students will participate;
4. Extend practice, reinforcement and feedback over a significant time frame;
5. Continually work on transfer of knowledge;
6. Encourage student reflection. (p. 103)

Thompson and Rubenstein (2000) recommended using a variety of strategies for teaching vocabulary, recognizing that there are different learning preferences which affect learner motivation. They also cited Gardner's multiple intelligences, as a means of addressing learning preferences when conceiving a variety of strategies including oral, written, visual, and kinesthetic modes for teaching vocabulary within a constructivist approach. Students should say aloud the word being learned, talk about its meaning, do writing activities that reinforce concepts and understanding, use visual representations (student-created or commercial products), and create activities that kinesthetically involve the student. Students need opportunities and guidance to acquire the meaning of vocabulary and make the words active. "Enculturating students to the vocabulary, phrasings, and meanings of mathematical language is a dimension of instruction that needs specific attention" (Thompson & Rubenstein, 2000, p. 573). According to

Miller (1993), "To assist students in making connections between language and mathematical empowerment, teachers should implement strategies that give all students an opportunity to construct, in both receptive and expressive modes, the formal language of mathematics" (pp. 313-314).

By way of example, in this study, the experimental group used their personal vocabulary journal as a tool for interacting with the mathematics vocabulary of eighth-grade pre-algebra. A first step when learning a new word was for the students to record what they already knew about the word in their vocabulary journals, giving them access to their own prior knowledge. As learners reflected on their experiences, their learning was enhanced by scaffolding with the assistance of the teacher and peers, enabling the students to complete their vocabulary journal entries beyond their unassisted efforts (Daniels, 2001, p.107). The use of language and shared experience is essential to successfully implementing scaffolding as a learning tool (Blake & Pope, 2008) and was used in this study. In order for students to be able to use their knowledge of vocabulary while applying it to class work and assessments, it is imperative that students construct their own mental models of the words to provide context based on their prior learning experiences. Each student is given an opportunity to describe each term in his or her own language and then have it checked for accuracy.

Experts agree that for a study of vocabulary to be meaningful and productive, students must understand the concept that underlies the definition (Burns, 2006). In order to make this happen in the classroom, students can become familiar with a new vocabulary word by discussing what the class knows about the term. Piaget and Inhelder (1969) hypothesized that assimilation and accommodation are important parts of a student's ability to make connections between old and new ideas and to construct and understand new mathematical ideas. If the class has no prior knowledge or conceptual understanding of the term, discussion should begin at a very concrete level and include direct and purposeful experiences. Simply supplying definitions for students will not be enough. Students must be directed toward the conventional meanings of vocabulary words yet also be offered the opportunity to develop their own understanding of the term. “Each time one prematurely teaches a child something he could have discovered himself the child is kept from inventing it and consequently from understanding it completely” (Piaget, 1970, p. 715). Piaget (1970) proposed that learning is not passive but interactive and that learners must experience a dynamic process, going through stages where they construct knowledge actively by creating and testing their own theories. This does not necessarily mean that the teacher cannot tell students anything directly. It simply means that even when listening to a lecture, the learner can be engaged and draw on previous knowledge to construct new knowledge.

Vygotsky, a Russian psychologist who is often compared to and contrasted with Piaget, reported that meanings evolve over time within social contexts (Vygotsky, 1962). Vygotsky believed that individual learners should regulate their own internal and external learning and should be assisted by educators within the individual’s zone of proximal development—the area between an individual’s level of performance and the level they could achieve if assisted. He recommended that students be encouraged to become independent learners using tools of language: draw it, talk about it, write about it, and even talk to themselves about it. All of these recommendations can be found in the vocabulary games the students will engage in to motivate them and to help them learn. Within the learning and the social context of group work in the classroom and in mathematics classroom discussions, the evolution of the individual has to take place within the individual learner, as he or she is continuously exposed to the word in context. The understanding of the vocabulary word would then deepen with repeated exposure and by the student refining and reconstructing his or her own concept and definition of the term. Sometime after the introduction to the new word, students revisited their vocabulary journals for additional activities with the word as described above. Students were asked to give examples, illustrations, and an OML definition of the word.

Steele (1999) asserted,

> Communication plays an important role in helping children construct links between their informal, intuitive notions and the abstract language and symbolism of mathematics; it also plays a key role in helping children make important connections among physical, pictorial, graphic, symbolic, verbal, and mental representations of mathematical ideas. (p. 26)

The vocabulary journal also provided space on each page for special directions, writing sentences using the term, and for drawings, charts, graphs, or graphic organizers, a page where students were given opportunities for further interaction with the word being studied. The teacher may give specific guidelines for this section or may simply ask the students to create or write something that illustrates their understanding of the vocabulary word or represents the meaning of the word.

The intervention for this study used Vygotsky's idea as discussed in Steel (1999), that learning takes place within the ZPD. Language and meaning develop together only when new vocabulary is presented in a meaningful context, that is, in the child's ZPD. Steele (1999) stated,

> Children learn new words by reflecting on, and picturing the meanings of the words in their minds as they interact. Through verbal expression of thoughts, children begin to reason for themselves. As children begin to use new words in the presence of a knowledgeable other person, they often find themselves in what Vygotsky called the zone of proximal development (ZPD), a place for learning

> that is located somewhere between the child's current understanding and potential understanding. (p. 38)

In the ZPD, the child's understanding of the concept may not be organized or may have inaccuracies that prevent the student from understanding or from reaching a higher level of learning. According to Jonassen (1994), "It is the job of the constructivist teacher to hold learners in their 'zone of proximal development' by providing just enough help and guidance, but not too much" (p. 163). In this study, when the vocabulary journal was revisited, the teacher and peers who were more advanced helped or assisted struggling students master ideas and concepts that they could not master on their own. Hung (2002) posited that "the teacher plays a central role in steering and facilitating the discussions and externalizations made" (p. 197). During the class discussions, the teacher or other person who is more knowledgeable is needed to concretize and standardize the definitions of the vocabulary word so its wording is acceptable in the mathematics community.

High-Stakes Tests and Mathematics Vocabulary

Professional educators in Indiana are required to prepare students for the ISTEP+. According to the Indiana Department of Education (2015) ISTEP+ Info Center the test assesses student grade-level knowledge and skills. The ISTEP+ is meant to provide insights on progress and to identify target areas for additional support. "Without exposure to vocabulary, they have a poor chance of successfully executing the required skill on state assessments. Mathematical vocabulary helps students acquire the conceptual knowledge they need to understand age-appropriate concepts" (Hea-Jin & Herner-Patnode, 2007, p. 122). An important and basic tool students need to succeed on high-stakes test questions is the ability to understand what the assessment is is asking the student to do in order to answer the question correctly.

Marzano and Pickering (2005) suggested that teaching vocabulary terms in a prescribed manner is perhaps the most important action a teacher can take to provide students with the knowledge they need to succeed in school. "The language of mathematics is a vital tool for student learning. Therefore, enculturating students to the vocabulary, phrasing, and meanings of mathematical language is a dimension of instruction that needs specific attention" (Thompson & Rubenstein, 2000, p. 573). By increasing students' vocabulary, students are adding to their background knowledge, acquiring a broader base to which they can relate new information, and making it easier for them to learn and understand new concepts. Increasing a student's vocabulary will also give students the opportunity to become more independent learners, making them less dependent on the teacher and capable of problem-solving on their own. NCTM (2000) made the following statement,

> Middle school students should have many opportunities to use language to communicate their mathematical ideas . . .. Writing and talking about their thinking clarifies students' ideas and gives the teacher valuable information from which to make instructional decisions. Emphasizing communication in a mathematics class helps shift the classroom from an environment in which students are totally dependent on the teacher to one in which students assume more responsibility for validating their own thinking. (pp. 78-79)

To be successful when taking high-stakes tests, it is essential that students be able to think and problem-solve without assistance or prompting from test facilitators. Students need to understand directions and vocabulary on their own. Some very simple examples of this include directions such as s*implify, evaluate or give the prime factorization*. Students who do not know the meanings of these directions will be unable to solve the problems correctly. If a student is asked to find the product or quotient and they do not know what these words mean, they will again be unable to solve the problems. In the classroom, students are often given clues or prompts from the teacher to help them know what to do, but on high-stakes tests they will not have this assistance.

Intervention Background

Graves (2006) asked the question, "What does it mean to know a word?" There is no simple answer for this question because words can be "known" on many levels, ranging from having no knowledge of the word whatsoever all the way to having a "rich, decontextualized knowledge of a word's meaning, its relationship to other words, and its extension to metaphorical uses, such as understanding what someone is doing when they are devouring a book" (Beck, McKeown, & Kucan, 2002). Harmon et al. (2005) found that research confirmed vocabulary teaching and learning in the content areas and should be mindful of the following principles: "(a) knowing a word fully is a continuous process; (b) wide reading is a critical venue for learning new words; (c) direct instruction plays an important role in vocabulary learning; and (d) integration, repetition, and meaningful use are critical features of effective vocabulary instruction" (p. 2).

The Intervention

Marzano and Pickering (2005) presented a six-step approach to teaching academic vocabulary designed to help students in building academic background knowledge that will aid them in understanding content encountered in school. I used these six steps and concepts from constructivist theorists in creating the directed study of mathematics vocabulary for the intervention for the experimental group in this study.

These are the six steps as stated in *Building Academic Vocabulary: Teacher's Manual* (Marzano & Pickering, 2005) and are printed with permission (Appendix A).

1. Provide a description, explanation, or example of the new term;
2. Ask students to restate the description, explanation, or example in their own words;

3. Ask students to construct a picture, symbol, or graphic representing the terms;
4. Engage students periodically in activities that help them add to their knowledge of the terms in their notebooks;
5. Periodically ask students to discuss the terms with one another;
6. Involve students periodically in games that allow them to play with the terms.

The process outlined above served as a guide for the directed study of the chosen mathematics vocabulary. Marzano and Pickering (2005) recommended that the first three steps be used together to ensure a proper introduction to each term and to assist students in the development of an initial understanding of each term. The last three steps provide multiple types of exposure that allow students to construct their understanding of the term through a variety of experiences over time.

Step 1: Provide a Description, Explanation, or Example of the New Term

This first step does not provide students with a definition of the term, nor does it ask students to look one up in a dictionary. The introduction of the term should be informal and provide a starting place for learning the term. An introduction to the new term begins by determining what students already know about the new word. This is done by having students go to their vocabulary journals where they are given two to three minutes to complete the question, “What do I already know about this word?” Students are then asked to reveal what they had written about the word in their vocabulary journal by discussing it with a partner or in a small group after which the entire class discusses highlights from their partner or group discussions. Misconceptions can be illuminated and dealt with and accurate knowledge can be built upon by the class. After this initial work with a new term, the class would then do the day’s lesson.

An initial interaction may also include an introductory activity. The five activities shown in Figure 1 below from Houghton Mifflin Harcourt's GO MATH Middle School Grade 8, were performed as an introduction for some of the vocabulary terms.

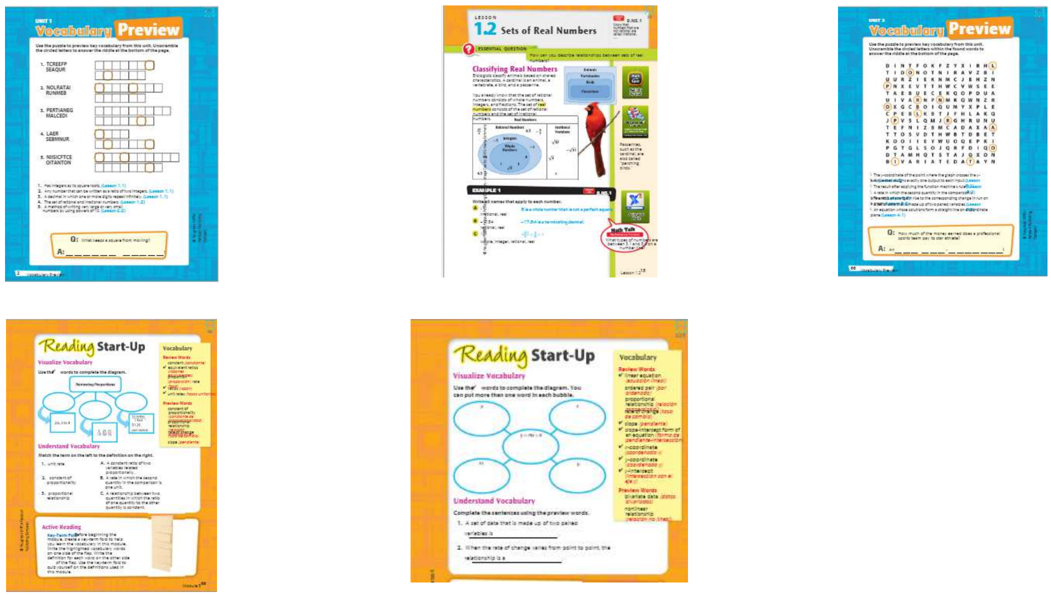


Figure 1. Five Activities to Introduce Vocabulary. From *GO MATH!,* Student Edition, Grade 8. Copyright © by Houghton Mifflin Harcourt Publishing Company. All rights reserved. Included by permission of the publisher, Houghton Mifflin Harcourt Publishing Company. (Appendix B)

Following an initial activity or discussion of the term, students begin constructing their understanding of a new term in one of many different ways. As Marzano and Pickering (2005) suggested, students watch a video, view images, discuss current events, or create a picture or drawing in their journals that targets the vocabulary term.

Step 2: Ask Students to Restate the Description, Explanation, or Example in Their Own Words

In Step 2, the student is asked to go to his/her own journal and restate in his/her own words his/her understanding of the new term. This requires the student to construct his/her own description, explanation, or example. The teacher then checks to be sure that major errors are absent from their understanding and remind them that they will have further opportunities to refine their ideas.

Step 3: Ask Students to Construct a Picture, Symbol, or Graphic Representing the Term or Phrase

In the first two steps, students are asked to use written or oral descriptions which require the students to process their new information linguistically. In this step, students are encouraged to think of the term in a different way. Now the student is asked to create a picture, symbol, or graphic representation of their understanding of the term that will force them to think non-linguistically. In this step, the teacher may have to provide models or examples for students who say they "can't draw" or allow students to work in partners to overcome their reluctance. The teacher may present a lesson focusing on how drawing and sketching are different. If students are at a loss, they can go to the Internet and search for images of the term to get ideas.

Step 4: Engage Students Periodically in Activities That Help Them Add to Their Knowledge of the Terms in Their Journals

Students would later revisit their vocabulary journals adding examples, illustrations and the OML definitions. Days or weeks later, students would again return to their journals for extended activities in which they were instructed to write sentences using the vocabulary word, do drawings, make charts, or use a graphic organizer to deepen their understanding of the word.

Through the use of activities provided by the teacher, students deepen their understanding of each term over time. Following these activities, students return to their vocabulary journals and revise their entries adding new information they learned such as a prefix, suffix, synonym, antonym, related word(s), cautions about confusions, or reminders about the term. As students continue to investigate a word and add to their knowledge of the word, they can begin to feel ownership of their new knowledge which, according to Jonassen (2003), "is the key to constructivism" (p. 29). Examples of such activities are detailed below.

Free association. The teacher announces that it is *free association* time. The teacher says a word such as *fraction*. Students think of a related word and can call it out, write it on a student whiteboard, put it in a classroom clicker, or make a list of related words on a piece of paper. If students wrote a list, they can exchange it with a partner and explain the words they each wrote. If students used a clicker, the teacher can use the responses to make a classroom list and use it for discussion. This activity has many possible variations.

Comparing terms. Figure 2 illustrates four different formats for comparing terms that are studied.

- ______________________ and ______________________ are *similar* because they both
- ____
- ____
- ____
- ________________________ and ________________________ are *different* because
- ________________ is ________________, but ________________ is ________________
- ________________ is ________________, but ________________ is

Figure 2. Comparing terms formula.

Sentence stems. Sentence stems provide structured guidance to help students think through a comparison and avoid common errors. See the example in Figure 3.

- __**rectangles**__________ and ____**squares**__________ are *similar* because they both
- Are polygons
- Have four sides which makes them both quadrilaterals
- Have four right angles

- __**rectangles**__________ and ____**squares**__________ are *different* because
- In a square all four sides must be equal, but in a rectangle only the parallel sides must be equal.
- ________________ is ________________, but ________________ is

Figure 3. Sentence stems example.

Venn diagram. Using a Venn diagram can help students compare similarities and differences of two words. Marzano and Pickering (2005) cautioned that students may need assistance in identifying "differences that are related to the same characteristic" (p. 41). To facilitate this, students can number each set of characteristics. See the example in Figure 4.

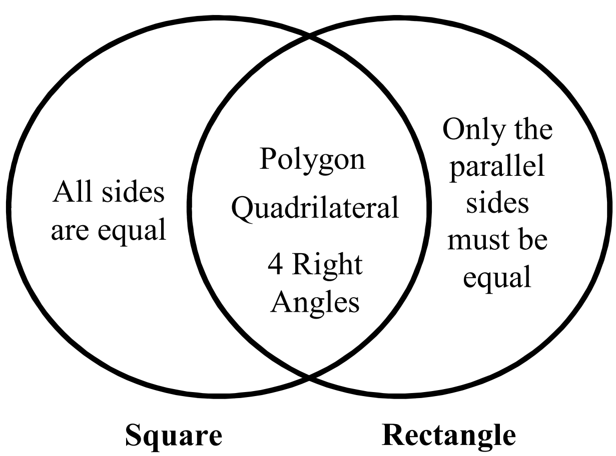


Figure 4. Using a Venn diagram to record similarites and differences.

Matrix. Students place the terms they are going to compare in the column headings (see Figure 5). This is a good method for comparing more than two items at a time, unlike the other methods of comparison illustrated above. The row headings are used to name the general characteristics that the students are comparing, and the cells of the matrix are used to describe each term as it relates to each characteristic (Marzano & Pickering, 2005). Once students have completed the matrix, they have organized the information about each term and can then proceed to think about and discuss the similarities and differences of the terms in the matrix. The matrices can be used by individual students or in group activities to engage students in lively discussions. Following these explorations, where students are constructing their meanings of the terms, they should be given time to make additions and revisions to their binder entries. These additions and revisions should always be monitored by the teacher to ensure accuracy and to provide assistance if the student shows any misconceptions (see Figure 6).

	Item 1	Item 2	Item 3	
Characteristic 1				Similarities & Differences
Characteristic 2				Similarities & Differences
Characteristic 3				Similarities & Differences

Figure 5. Template of matrix graphic organizer.

	Addition of Numbers in Scientific Notation	**Subtraction** of Numbers in Scientific Notation	**Multiplication & Division** of Numbers in Scientific Notation	Similarities & Differences
Exponents	The exponents must be equal BEFORE adding	The exponents must be equal BEFORE subtracting	ADD the exponents when multiplying. SUBTRACT the exponents when dividing.	In addition & subtraction the exponents must be EQUAL. But in multiplication and division, they do NOT have to be equal.
Coefficients	AFTER making the exponents the same, ADD the coefficients	AFTER making the exponents the same, SUBTRACT the coefficients	MULTIPLY the coefficients in a multiplication problem. DIVIDE the coefficients in a division problem.	The coefficients in all problems math the operation you are doing. Add, subtract, multiply, or divide according to the problem being done.
Final Answer	Write the answer as $N \times 10^x$	Write the answer as $N \times 10^x$	Write the answer as $N \times 10^x$	Answers in scientific notation are written as $N \times 10^x$ where N is a number between 1 and 10 and x is an integer.

Figure 6. Example of matrix graphic organizer.

Classifying terms. In this activity, students are challenged to group terms on the basis of similar attributes. The task may be structured by giving students terms and the categories into which they must place them. For example, they might classify a list of triangles or pictures of triangles and be asked to classify them by the lengths of their sides or by the sizes of their angles. The activity could be more open-ended by providing either the triangles or the categories, but not both. Another procedure would be to create categories for students and ask them to go through their vocabulary journals, searching for terms that fit into the given categories. These activities can be performed individually, in pairs, or in small groups, while emphasizing that the students can explain (a) the criteria for membership in a category, (b) the items they included in each category, and (c) how each item meets the criteria for placement in a category (Marzano & Pickering, 2005).

Step 5: Periodically Ask Students to Discuss the Terms With One Another and In the Class

Interacting with others about what is being learned deepens the understanding of everyone involved in the discussion. These discussions can be informal or can be more structured. Once such structure is think-pair-share. First, students are given time to think individually about what they have put in their vocabulary journals. Secondly, the teacher pairs up the students and asks them to discuss their descriptions and pictures, identifying areas of disagreement or confusion, clarifying what is correct and what is not. The final step is for students to share aloud with the entire class. It is here that interesting ideas can be shared, and misconceptions and confusing ideas can be resolved accurately. Once this is done, students can go back to their vocabulary journals and once again revise and edit their entries for the term being discussed.

After students have explored a vocabulary word on several occasions, there is eventually a time they are required to write the OML definition of the word. This is a very important part of the intervention. Jonassen (1994) suggested, "Perhaps the most common misconception of constructivism is the inference that we each therefore construct a unique reality, that reality is only in the mind of the knower, which will doubtlessly lead to intellectual anarchy" (p. 27). This is the point where the teacher can guide the class to socially negotiate an acceptable definition for the term which was being studied and guarantee that the definition is conventionally accurate.

Step 6: Involve Students Periodically in Games That Allow Them to Play With

Terms

Games are a great tool to help keep the new terms in the students' thinking and provide them with the chance to reexamine their understanding of the terms they have learned. They are a great way to review many terms at one time. Fridays in the classroom were game days where students got to use the vocabulary in game situations. Engaging in activities was highly motivational and through them, students were willing and anxious to revisit previous vocabulary words. Some of the games used in this study are detailed below.

What is the question? This game is modeled after the television show, *Jeopardy!* Templates for this game can be found online using PowerPoint or other presentation software. Other options for creating the game include using a transparency or a whiteboard if appropriate technology is not available. It is also possible to purchase the *Jeopardy!* game console that allows teachers to input and save games on a game cartridge. The teacher can create the game using words or images, and it can be played in pairs, groups, or teams.

Vocabulary charades. Patterned after the popular parlor game, this game requires students to actively and silently act out the vocabulary term or concept. One way to play the game is for students to stand up by their desks and act out a term called out by the teacher. Another way is for students to form teams and then give designated team members a term and have a player on each team act it out, trying to beat the other team before they guess the term. There are many variations that can be played.

Classroom password. This game is patterned after another television game show, Password. Previously studied vocabulary words are separately written on cards. A student volunteer comes to the front and draws a card. He/she may give a one-word clue to the class who tries to guess the word from the clue. The student continues to give one-word clues to the class until the word is guessed. Each word is worth 100 points and goes down 10 points each time another clue is given. A total score is kept for each class and at the end of the day the winning class gets a prize!

I have, who has? Students are given a card as shown in Figure 7. The teacher has prepared a list of terms that have been previously studied and places them on separate pieces of paper then puts them in a basket. Each student draws a vocabulary word from the basket without looking. Students are instructed to refer to the OML definition of their word in their vocabulary journal and write it where it says, "Who has." The teacher collects the cards and fills in the blanks on the card "I have" from the list of vocabulary words so that the game will progress from one card to the next, ending with the first card.

I have ____________

Who has… (students write definition here.)

Figure 7. I have, who has?

Vocabulary word hunt. Before students enter the classroom, the teacher places definitions around the room on brightly colored pieces of paper. Underneath each definition there is a vocabulary word that does *not* match the definition. Students are assigned a definition located the in room. They must find the word that matches that definition and write it on their answer sheet. They read the definition on this new sheet then go find the word that matches it and write it on their answer sheet, read the new definition, find the new word on another sheet and so on. When they return to their original definition, they are finished. The teacher can easily grade the papers by checking to see if the words are in the correct order.

Hangman. The teacher chooses one person to be the "host." The host chooses a secret word from his/her vocabulary journal and draws a blank line for each letter in the word. The class starts guessing letters while the hosts keeps track of guessed letters. The host fills the letter in the blanks if the players guess correctly. The host draws part of the "hangman" when the players guess wrong.

Conclusion

This review of the literature has clearly demonstrated the importance of conceptual understanding and fluency of vocabulary across the disciplines, including mathematics. In order for a direct study of mathematics vocabulary to be effective, the literature demonstrates that it should include word etymology, address confusing terms, provide opportunities for students to develop an understanding of concepts the words represent, use a variety of representations (both student-created and commercial), and deal with the unique characteristics of mathematical words and symbols. Because very little research has been done to determine if a direct study of vocabulary has a significant effect on student performance on high-stakes questions, this study is needed to add to the body of knowledge so that teachers may make more informed curriculum decisions within their own classrooms.

CHAPTER 3

METHODOLOGY

At the schools where this study took place, students were placed in classes based on seventh-grade ISTEP+ scores, previous mathematics grades, previous test scores from the Acuity Assessment System (2016) given to students quarterly to assess readiness for ISTEP+, and teacher recommendations. The highest scoring students were placed in Algebra I classes, and the remaining were placed in pre-algebra classes. I was the teacher for students in the experimental group. The classes at the control group school all had the same teacher. I instituted interventions equally across classes in the experimental group, and the teacher for the control group taught in a traditional educational setting. Both the control and experimental groups were taught using the Grade 8 Indiana Standards for Mathematics (see Table 2). Both schools followed the order of topics below during the experimental timeframe from August 2016 to December 2016. The population remained stable, with approximately 130 students in six classrooms participating for an entire school year.

Table 2

Pre-Requisites by Quarter

Quarter	Pre-Requisites
Quarter 1	PR1 – Order of Operations PR2 – Integers and Absolute Value PR3 – Adding and Subtracting Integers PR4 – Multiplying and Dividing Integers PR5 – Solving Equations by Adding and Subtracting PR6 – Solving Equations by Multiplying and Dividing PR7 – Percentage Values Unit 1 Number Sense Rational and Irrational Numbers (8.NS.1) Solving by Using Square Roots, Estimate Irrational Square Roots (8.NS.2 & 8.NS.4) Exponent Laws (8.NS.3) Equivalent Expressions with Exponents (8.NS.3) Scientific Notation Ordering, Multiplying, and Dividing (8.C.2) Unit 2 Rational Equations 2-1 Add and Subtract Fraction Expressions and Equations (8.AF.1) 2-2 Multiply and Divide Fraction Expressions and Equations (8.AF.1) 2-3 Add, Subtract, Multiply and Divide Fraction Word Problems (8.AF.1 and 8.C.1) Unit 3 Multi-Step Equations 3-1 Multi-Step Equations: Integers with one variable (7^{th} grade skill review) Day 1: Just two step Day 2: Combining Like Terms Day 3: Distributive Property 3-2 Variables on both sides: Integers (8.AF.1) 3-3 Special Solutions: Integers (8.AF.1 and 8.AF.2)

Quarter	Pre-Requisites
Quarter 2	Unit 4 Linear Functions 4-1 Defining and Recognizing a Function (8.AF.3) 4-2 Making a Graph of a Function (8.AF.4) 4-3 Finding Slope from a Graph and Points 4-4 Understanding Slope-Intercept Form (Identifying slope and y-intercept from an equation) 4-5 Graphing Using Slope-Intercept Form (8.AF.5) 4-6 Slope-Intercept Form Word Problems (8.AF.6)

The purpose of this quasi-experimental study was to determine whether there is a significant effect from a directed study of mathematics vocabulary on high-stakes standardized mathematical questions for eighth-grade students enrolled in pre-algebra in a rural school in southern Indiana. The study took place during the 2016-2017 school year; I quantitatively examined student performance on pre- and posttests created using the Acuity Assessment System. I administered the pretest in August 2016 and the posttest in December 2016. The independent variable was the treatment, a directed study of mathematics vocabulary designed by me, which is described in detail later in this chapter. The dependent variable was the posttest score. The curriculum used by both the control group teacher and the experimental group teacher was based on the content of the 2014 Indiana Academic Standards for Mathematics for Grade 8 (Indiana Academic Standards, 2015).

A qualitative component was used in this quasi-experimental study in order to ensure the nature of instruction and content coverage in the control classroom. These data were gathered from classroom observations of the control group teacher and an interview of the control group teacher upon completion of the study, but they were not used for making assertions regarding the study's research questions. Descriptive data were also gathered in order to understand the effect of the journal component of the intervention. Data associated with the journal included the journals, which were reviewed and scored by me as noted elsewhere, and my own fieldnotes taken during the time of the intervention. Although descriptive data were gathered from an analysis of the vocabulary journals completed by students in the treatment group, those data were also considered inferentially to ascertain any significant correlation with test scores.

The use of vocabulary journals in the experimental group provided students with a structure for engaging with each word. When a new word was introduced, students were asked to access their prior knowledge by answering the question, “What do I already know about this word?” When appropriate, examples were discussed and entered into the journal. At a later time, usually a day or two later, students were asked to enter an OML definition that had been agreed upon by the class, cited in the text, or retrieved from the glossary. OML definitions were clear and 90-100% were accurate. After 12 of the words had been studied, a classroom activity was conducted in which students worked in pairs to create illustrations for the words that had been studied. Students were permitted to use their textbooks and the internet to help them craft their illustrations. This proved to be a challenging activity that demonstrated limited understanding of the underlying concepts for most of the vocabulary terms. Overall, finding time in the classroom to complete the journals was a challenge. I collected journals from all students; however, only those students who were in the study had their journals scrubbed by the RA then analyzed by me with the rubric. Generally, work in these journals was presented in an organized fashion and assigned entries were completed with few mathematical errors; however, some were hard to read at times, as if they were done in a hurry.

I noted in the field notes that students generally complained about being asked to write in their vocabulary journals and rushed through their journal work as quickly as they could. They had to constantly be reminded to complete them and to rate their understanding of the word in the space provided at the top of each page. Many commented during journal activities they did not know what to write or draw. The students did not like this activity because there was no right or wrong answer, and it required a higher level of thinking about the word.

During the course of the study, I observed the control group teacher during eight periods in her classroom on two separate school days in October and December 2016. On both visits to the control group teacher's classroom, I noticed that the room temperature was a chilly 65 degrees. The windows on the north side of the room let in sunlight even though they were partially covered with blinds. Student desks consisted of a student table and chair and were arranged in six groups of five with two pairs facing and one desk at the end, allowing seating in the room for 30 students. A television was suspended in the front of the classroom and had a digital clock on it that was synchronized with the bell system. A smart board was next to the television in the front on the east side of the room. Each student had a Chrome Book, but students did not use them during either of my visits. In the experimental classroom, the temperature was usually a warm 78 degrees and desks were arranged in six rows of five each, seating a total of 30 students. There were no exterior windows, only florescent lighting, which were usually set so only half of them are on. A 30 x 30 section of the room had the student desks and a Promethean Board in the front of the room. The other half had 30 desktop computers set up on tables in four rows. The computers were used for completing homework assignments through Houghton Mifflin Harcourt software for the classroom series *Go Math* (Burger et. al., 2014) and *IXL* (https://www.ixl.com/) online. *IXL* (from "I excel") is a math and language arts subscription-based practice website for K-12 and has unlimited questions on thousands of math topics and a comprehensive reporting system.

Research Questions

From past studies, it has been posited that vocabulary understanding and understanding of the language of mathematics is critical to student performance in the classroom and on high-stakes mathematical tests (Burns, 2006; Riccomini et. al., 2015). The current study was designed to determine if a directed study of vocabulary could address such a concern. As such, the research questions studied were as follows.

1. Does a directed study of mathematics vocabulary significantly affect student performance levels on standardized mathematical questions?
2. Will the strategies used in this study significantly affect student performance levels on standardized mathematical questions?

To determine a significant effect, the following null hypotheses must be rejected:

$H1_0$: A directed study of mathematics vocabulary has no significant effect on student performance levels on standardized mathematical questions.

$H2_0$: The strategies used in this directed study of mathematics vocabulary have no significant effect on student performance levels on standardized mathematical questions.

I used the same outcomes data to answer both of these questions; however, the second question's answer was augmented by my review of the vocabulary journals, the interview/observations of the control teacher, and field notes.

Participants

The school for the treatment group was a middle school (Grades 7 and 8) in southern Indiana, with an enrollment of approximately 430. The control group came from a neighboring school with an enrollment of 867 in Grades 6, 7, and 8. Both schools were in rural districts that have approximately a 55% free or reduced lunch rate (IDOE, 2017b). According to the IDOE (2017a), the control school was 96% White having six Asian, two Black, 12 Hispanic, and 14 multiracial students out of 867 students in the school. The control school had two English language learners (ELL) and 18% of the school's population were in special education. The experimental school was 95% White, having one American Indian, four Asian, two Black, three

Hispanic, and eight multiracial students out of 377 students in the school. The experimental school had 21% of its enrolled students in special education and no ELL students.

The following paragraphs explain the process used for assigning students to pre-algebra classes at both of the schools. Both groups were convenience sample, based on guidance-counselor assigned placements.

For the 2016-2017 school year, I was assigned to teach six eighth-grade pre-algebra classes that were observed to be consisting of 78 male and 60 female students ranging from ages 13 to 15. Students in the experimental group were designated as subjects if they had parent permission and gave student assent (n = 80). Students taking eighth-grade Algebra I were removed from the pool of eighth graders, and the remaining students, including special education students, made the pool from which the guidance counselor created the six pre-algebra classes. Class sizes ranged in number from 14 to 30 students per class. I taught the students from these classes using the directed study of mathematics vocabulary that I created for this study.

The control group was created from a neighboring middle school located in a different school district. The process for selecting students for pre-algebra classes was the same for both schools. All eighth-grade students who were *not* in an Algebra I class for high school credit were placed in eighth-grade pre-algebra classes by the school guidance counselor. The control teacher was assigned four pre-algebra classes that were observed to consist of 45 male and 44 female students ranging from ages 13 to 15. Students in the control group were designated as subjects if they had parent permission and gave student assent (n = 37). Students in the control group were taught as this teacher normally taught. The control group teacher was recommended to me by the school counselor based solely on his opinion that she would be the better of the two pre-algebra teachers at the control group school for the current study. The classes for the control group numbered 15 to 25 per classroom and were taught singly by this teacher and contributed to the study by taking the same pretests and posttests during the same time periods that the experimental group took the same tests.

Parental Consent and Student Assent

Parents of the students for both the treatment and control groups were given a form in the school's registration packets in August 2016 notifying them of the study, the extent, and the conditions of their child's participation, and the option of nonparticipation with the ability to opt out at any time (Appendix C). Along with the permission form, parents also received an envelope with instructions for turning in the form. Because the students are adolescents having the capacity to comprehend the nature of the research activity, prospective participants received a consent form enumerating what their participation in the research would involve, a statement of minimal risk, and the option of nonparticipation with the ability to opt out at any time (Appendix C). These forms were given to the students in their math class by the research assistant (RA) when the teacher was not present. The RA read a script after which students made their decisions and returned it to the RA in an envelope. Identities of all students were scrubbed from pretests and posttests by the RA when data was collected so that chances of coercion to participate were minimized. All pre-algebra students from the experimental group's school participated in the directed study, as it was part of the school year's curriculum and teaching for all students; however, only the data from students who had assented to participate and whose parents agreed to let me use the data were used.

Research Design

This was a quasi-experimental study using a repeated-measures ANCOVA to analyze scores from a mathematics vocabulary pretest and posttest for each participant. Dimitrov and Rumrill (2003) stated, "The purpose of using the pretest scores as a covariate in ANCOVA with a pretest-posttest design is to (a) reduce the error variance and (b) eliminate systematic bias" (p.

161). Further understanding of the data outcomes from these two tests in relationship to the intervention was supplemented by a review of students' vocabulary journals, including investigation of possible correlations between the journal's rubric-scored outcomes and test data. I kept field notes throughout the intervention in order to recall specific events relative to recommendations for future practice. A qualitative component was also used to ensure the nature of instruction and content coverage in the control classroom; this gathered through observations of the control teacher in her classroom and an interview with the control teacher after the posttest was given in December 2016 (Appendix D). Again, these data were to ensure assumptions about the control classroom but were not part of the data collected for the research questions.

I conducted the study in a traditional educational setting using normal educational practices. The study included multiple choice test questions written by me using the Acuity Assessment System (2016) for the testing of the students. The mathematics vocabulary treatment was administered to the treatment group between the administrations of the pretest and posttest. The treatment, explained later in this chapter, included a vocabulary journal for each participant. Upon completion of the treatment, I reviewed the students' journals along with my observation notes during the study in order to provide supplementary insights, and to determine if a correlation existed between the journals and treatment group test scores.

The population consisted of eighth-grade pre-algebra students from two different middle schools in southern Indiana (see Participants section in Chapter 3) This quasi-experimental study was of a quantitative, repeated-measures design using a population of approximately 140 eighth-grade students. A total of 80 students scattered throughout six classes returned parent permission forms and gave assent to have their data used in the study. All students in the experimental group received the treatment (a directed study of mathematics vocabulary designed and taught by me). At the end of the study in December 2016, the sample was 52. Only these 52 subjects had completed pretests, posttests, and journals. This group was referred to as the treatment group. The treatment is presented in detail later in this chapter. Approximately 45 students, arranged in three classes from a neighboring middle school located in a different school district, formed the control group. Two students from the control group voluntarily withdrew during the study by signing the statement on the posttest answer key, "If you have changed your mind and you wish to withdraw your data from the study, you may do so by signing your name here." Six students in the control had incomplete data missing either the pretest or the posttest. This left a sample of 37 for the control group.

The teacher for the control group taught her classes as she normally would. During the study, I observed the control group teacher for a total of over 8 hours per day for one day in November and one day in December. Using the protocol of questions in Appendix D, the control group teacher was interviewed upon completion of the study in December 2016. This information is included in the results chapter to help answer the research question, "Will the strategies used in this study significantly affect student performance levels on standardized mathematical questions?" Specifically, the interview and classroom observations ensured that the vocabulary strategies used in the intervention were not used in the control group. The teacher administered a pretest and a posttest created with Acuity Assessment System (2016) from CTB-McGraw Hill. As an educator, I had custom test-building and item-authoring capabilities, access to standards-based item banks, and over 2,000 Common Core-aligned questions. Both the pretest and posttest focused on vocabulary words and their concepts selected from the 2014 Indiana Academic Standards for Mathematics for Grade 8 (IDOE, 2015a).

In Acuity, teachers have the option of creating their own tests using the bank of questions created by McGraw-Hill Education (MHE) for such tests as ISTEP+, the Smarter Balanced™, and PARCC® summative assessments. Due to this fact, it can be assumed that "educators can trust that the assessment results are valid and reliable" (Acuity, n.d., para 2).

Before participating in the experiment as either a student in the control or experimental group, all students took the first of the two Acuity exams that I created from the Acuity test bank of questions specifically related to the target vocabulary, the pretest. All students in both groups took the same paper and pencil pretest during the same week of school. A script for giving the tests and the test itself can be found in Appendix E of this document.

All answer sheets at both schools had a cover sheet on which students entered their school name, math period, first and last names, and date (Appendix E). The cover sheet was attached to the answer sheet on which there was an area for the RA to place a personalized code number for each student. At the experimental group's school, the RA collected completed tests each period and placed them in a box for processing by the RA. At the control group's school, all tests, cover sheets, and answer sheets were placed in a box by the control group teacher and taped shut for me to pick up. Upon receiving the testing materials from each school, the RA, a CITI certified teacher, removed, and shredded the tests of students who were not participating in the study. Using class lists, the RA assigned a number to each student and recorded it for future reference when needed for the posttest. The RA secured this list in a locked file cabinet after recording the participating students' code numbers on their answer sheets and scrubbing the cover sheets. The RA then presented the scrubbed tests to me for scoring. I scored and recorded the pretest results and entered them into SPSS software for data review. The same procedure was repeated after the students took the posttests at the end of the study.

Phase 2 consisted of the implementation of the directed study of mathematics vocabulary to the treatment group for a 12-week period from August 2016 to December 2016. The posttest was given to both groups and collection of the documents proceeded in the same manner as with the pretests. All data was collected and analyzed statistically using an analysis of covariance (ANCOVA) to determine if there was a significant effect from a directed study of mathematics vocabulary on student performance levels on standardized mathematical questions and if the strategies used in the directed study of vocabulary had a significant effect on student performance levels on standardized mathematical questions.

I chose ANCOVA for the statistical test to assure homogeneity when comparing the means of the pretest and posttest. Owen and Froman (1998) stated, "As many statistics books point out, the analysis of covariance (ANCOVA) has two primary purposes: (a) to improve the power of a statistical analysis by reducing error variance, and (b) to statistically 'equate' comparison groups" (p. 557).

One of the pieces of descriptive data that was evaluated and subsequently analyzed inferentially in a supplementary fashion to this study's main research questions was the student vocabulary journals. The journals were rated using the rubric entitled, "Rubric for Math Vocabulary Journal" (Figure 8). The rubric was created using *RubiStar,* an online free tool to help teachers create quality rubrics (ALTEC at University of Kansas, 2017). Close attention was given to students' understanding of mathematical concepts and their use of OML. Using a scale where 4 is high and 1 is low, student vocabulary journal scores were matched with the quantitative scores from the pretests and posttests, searching for any patterns that might appear.

Rubric Made Using:
RubiStar (http://rubistar.4teachers.org)

Rubric for Math Vocabulary Journal

Teacher Name: **Mrs. Waite** **Date _______________**

Period _____ Student Name: ____

CATEGORY	4	3	2	1
Neatness and Organization	The work is presented in a neat, clear, organized fashion that is easy to read.	The work is presented in a neat and organized fashion that is usually easy to read.	The work is presented in an organized fashion but may be hard to read at times.	The work appears sloppy and unorganized. It is hard to know what information goes together.
Mathematical Errors	90-100% of the information has no mathematical errors.	Almost all (85-89%) of the information has no mathematical errors.	Most (75-84%) of the information has no mathematical errors.	More than 75% of the information has mathematical errors.
Mathematical Concepts	Explanation shows complete understanding of the mathematical concepts.	Explanation shows substantial understanding of the mathematical concepts.	Explanation shows some understanding of the mathematical concepts.	Explanation shows very limited understanding of the underlying concepts.
Official Mathematics Language (OML)	OML definitions are clear and 90-100% are accurate.	OML definitions are clear and almost all (85-89%) are accurate.	OML definitions are mostly clear and (75-84%) are accurate.	More than 75% of the OML definitions are unclear and inaccurate.
Completion	Assigned entries are completed.	All but one of the assigned entries are completed.	All but two of the assigned entries are completed.	Several of the assigned entries are not completed.

Figure 8. Rubric for math vocabulary journal.

The use of vocabulary journals in the experimental group provided students with a structure for engaging with each word. When a new word was introduced, students were asked to access their prior knowledge by answering the question, “What do I already know about this word?” When appropriate, examples were discussed and entered into the journal. At a later time, usually one or two days later, students were asked to enter an OML definition which had been agreed upon by the class, cited in the text, or retrieved from the glossary. OML definitions were clear and 90-100% were accurate. After 12 of the words had been studied, a classroom activity was conducted in which students could work in pairs to create illustrations for the words that had been studied. Students were permitted to use their textbook and the Internet to help them craft their illustrations. This proved to be a challenging activity that demonstrated limited understanding of the underlying concepts for most of the vocabulary terms. Journals were collected from all students; however, only those students who were in the study had their journals scrubbed by the RA then graded by me with the rubric. Generally, work in these journals was presented in an organized fashion and assigned entries were completed with few mathematical errors; however, some were hard to read at times, as if they were done in a hurry.

During the course of the study, I observed the control group teacher during eight periods in her classroom on two separate school days in October and December 2016. While observing at the control school, I concluded that overall classroom routines and teaching styles were very similar. Both teachers began class with bell work that students were to begin as soon as the bell rang to start class. The material covered in bell work either reviewed topics from the day before or previewed what the students would be covering that day in class. This work was completed by the students then discussed with the entire class and may or may not be collected for a grade. Next, the new topic and the state standard that covers it were introduced and taught to the entire class using a smart board and interactive examples. Students were given practice then assigned homework over the material which was due the next day. Homework was turned in the next day in the experimental group's class and at the end of the week for the control classroom. Homework may or may not be graded and recorded in the control group class. Students in my classes turned in homework 3 days a week. Homework was graded by me and returned to students the next day. My students were required to correct homework mistakes and turn them back in for bonus points. When corrected, each missed problem that was done correctly received a half point added to his or her grade as extra credit.

The only time vocabulary was addressed in the control group classroom was when a term was used and the teacher would say something like, "Remember this word. It means . . .." The teacher would then tell the class the definition but did not ask students to write it down or use it in any way. Sometimes she would voice frustration that no one could remember the definition and would make a comment such as, "Don't you remember? We talked about it last week."

The qualitative data gained from two unannounced observations of the control group teacher (observing during the teaching of four periods of pre-algebra for each visit) were analyzed for the purpose of comparing and contrasting teaching methods used in both the control and treatment groups. I aimed to identify whether students in each group received instruction that would account for similarities or differences in the results of the final quantitative data. Interviewing the control teacher after the observations were completed helped provide additional insight into how the teaching of mathematical vocabulary was or was not presented in her classroom and helped with the interpretation of data at the completion of the study.

Description of Directed Study of Vocabulary Instructional Intervention

According to Marzano and Pickering (2005), "Teaching specific terms in a specific way is probably the strongest action a teacher can take to ensure that students have the academic background knowledge they need to understand the content they will encounter in school" (p. 1). The authors offered a six-step process for teaching vocabulary through a direct approach:

> The first three steps, used as a set, ensure that teachers appropriately introduce a new term and help students develop an initial understanding of it. The last three steps describe different types of multiple exposures that students should experience over time to help them shape and sharpen their understanding of the terms, helping to make them a part of their academic background knowledge (Marzano & Pickering, 2005, p. 14).

The steps include the following:

1. Provide a description, explanation, or example of the new term;
2. Ask students to restate the description, explanation, or example in their own words;
3. Ask students to construct a picture, symbol, or graphic representing the term;
4. Engage students periodically in activities that help them add to their knowledge of the terms in their notebooks;
5. Periodically ask students to discuss the terms with one another;
6. Involve students periodically in games that allow them to play with terms. (pp. 15-30)

This process, used along with a student vocabulary journal, helped students in the classroom form a common core of background knowledge for the pre-algebra vocabulary used in the study.

The Frayer model of concept attainment (Figure 9), "which encompasses a structured and systematic procedure for defining concepts" (Peters, 1975, p. 252), is based upon results obtained from research related to conceptual learning.

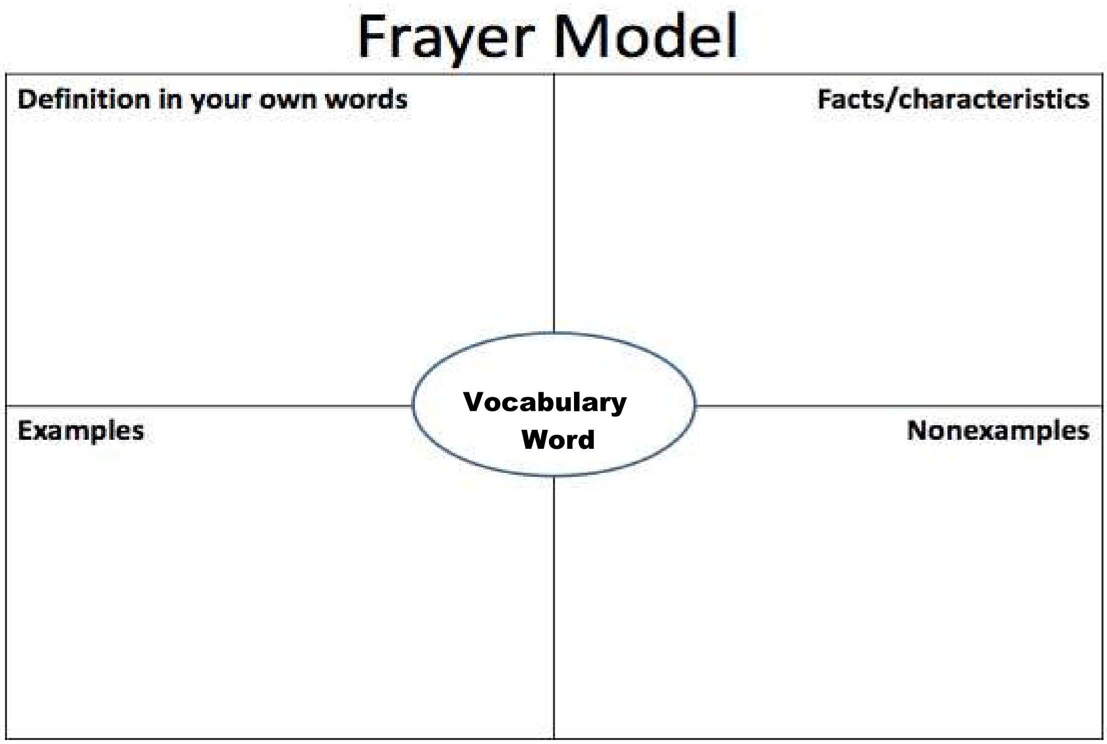


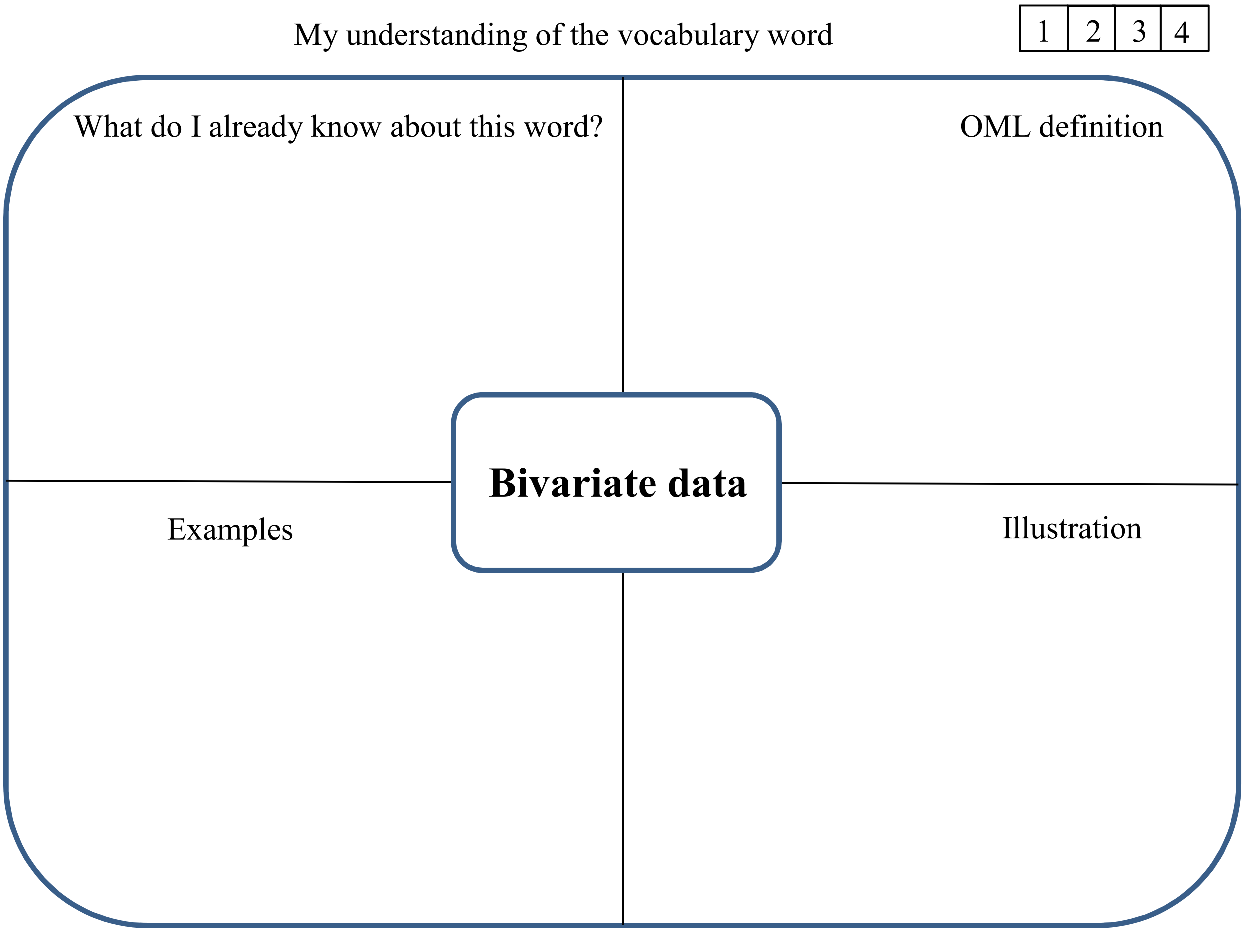
Figure 9. The Frayer model of concept attainment.

All students using the directed study of vocabulary in the mathematics classroom were given a vocabulary journal to use for their study of mathematics vocabulary. I modified the Frayer model (Figure 9) and expanded the model as shown below in Figure 11. The vocabulary journal consisted of a teacher-created Table of Contents (Figure 10) and vocabulary pages for each of the vocabulary words as illustrated in Figure 11. During the 12 weeks of the intervention, there was only enough class time to study the bold/italicized words shown in the Table of Contents. The rest of the words were covered during the remainder of the school year, but were not part of this study.

Page #	Vocabulary Word	Location
1	alternate exterior angles	Module 11
2	alternate interior angles	Module 11
3	***bivariate data***	***Module 5***
4	center of dilation	Module 10
5	center of rotation	Module 9
6	Cluster	Module 14
7	conditional relative frequency	Module 15
8	Cone	Module 13
9	Congruent	Module 9
10	***constant of proportionality***	***Module 3***
11	corresponding angles	Module 11
12	***cube root***	***Module 1***
13	Cylinder	Module 13
14	Dilation	Module 10
15	enlargement	Module 10
16	exterior angle	Module 11
17	frequency	Module 15
18	function	Module 6
19	hypotenuse	Module 12
20	Image	Module 9
21	***Input***	***Module 6***
22	interior angle	Module 11
23	***irrational number***	***Module 1***
24	joint relative frequency	Module 15
25	Legs	Module 12
26	line of reflection	Module 9
27	***linear equation***	***Module 4***
28	linear function	Module 6
29	marginal relative frequency	Module 15
30	nonlinear relationship	Module 5
31	outlier	Module 14
32	***output***	***Module 6***
33	perfect number	Module 1
34	***perfect square***	***Module 1***

Page #	Vocabulary Word	Location
35	preimage	Module 9
36	***principal square root***	***Module 1***
37	***proportional relationship***	***Module 3***
38	Pythagorean Theorem	Module 12
39	***rational number***	***Module 1***
40	***real number***	***Module 1***
41	reduction	Module 10
42	reflection	Module 9
43	relative frequency	Module 15
44	remote interior angle	Module 11
45	***repeating decimal***	***Module 1***
46	rotation	Module 9
47	same-side interior angles	Module 11
48	scale factor	Module 10
49	***scatter plot***	***Module 14***
50	***scientific notation***	***Module 2***
51	similar	Module 10 & 11
52	***slope***	***Module 3***
53	***slope-intercept form of an equation***	***Module 4***
54	solution of a system of equations	Module 8
55	sphere	Module 13
56	***square root***	***Module 1***
57	system of equations	Module 8
58	***terminating decimal***	***Module 1***
59	transformation	Module 9
60	translation	Module 9
61	transversal	Module 11
62	trend line	Module 14
63	two-way frequency table	Module 15
64	two-way relative frequency table	Module 15
65	two-way table	Module 15
66	***y-intercept***	***Module 4***

Figure 10. Table of contents for student vocabulary journal.



The space below can be used for special directions, to write sentences using the term, drawings, charts, graphs, or graphic organizers.

Figure 11. Revised vocabulary model for use in this study.

The introduction of each new term began with a classroom discussion, a video, or an activity to help students recall prior knowledge that related to the new vocabulary word and its underlying concepts. Following the introduction of the new term or concept and using the format illustrated in Figure 11, students were directed to offer a description of the term in their own words. They were asked to list all of the facts they knew about the term and to give examples. At times this was done individually and at other times students collaborated in groups, or as a class. Examples and non-examples (non-examples have some but not all of the characteristics of the new term being discussed) were solicited and recorded. If there was a root word for the term being studied, it was discussed.

At a later time, on a different day when the term was used again, the class went back and added to the information in their vocabulary notebooks. As the term was revisited over the following days and weeks, students were directed to go back to their journals and write a formal definition using OML use the term in a sentence, create problems using the concepts, illustrate the term, or other activities appropriate for developing a deeper understanding. Each Friday, the teacher implemented vocabulary games and activities to increase fluency and automaticity when using the term. The purpose of the journal was to provide students with a meaningful resource that helped cultivate an understanding of the terms and concepts being used in their math lessons.

Vocabulary for the Study

Although there are many vocabulary lists available for the study of pre-algebra in eighth grade, the vocabulary words were chosen from the IDOE (2015b) website. The vocabulary in the intervention for this study is highlighted below within the context of the Indiana Academic Standards for Eighth Grade Mathematics followed by the DOE's definition for each highlighted term (Table 3). The intervention also included assessment vocabulary taken from the ISTEP+ Standards and Assessment Vocabulary (n.d.). Vocabulary was also used in the intervention for the purpose of preparing students for standardized assessments by familiarizing them with words and phrases they may frequently encounter when answering high-stakes multiple-choice test questions (Table 4).

Table 3

Vocabulary Studied in the Intervention

	Indiana Academic Standard for Eighth Grade Mathematics – Adopted April 2014	Highlighted Vocabulary Words from the Standard Defined
	Number Sense	
MA.8.NS.1:	Give examples of rational and irrational numbers and explain the difference between them. Understand that every number has a decimal expansion; for rational numbers, show that the decimal expansion repeats eventually, and convert a decimal expansion that repeats into a rational number.	Rational number - a real number that can be written as a ratio of two integers with a non-zero denominator. Irrational number - a real number that cannot be expressed as a ratio of two integers.
	Computation	
MA.8.C.2:	**Solve real-world and other mathematical problems involving numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. Interpret scientific notation that has been generated by technology, such as a scientific calculator, graphing calculator, or excel spreadsheet.**	Scientific notation - a method for expressing a given quantity as a number having significant digits necessary for a specified degree of accuracy, multiplied by 10 to the appropriate power, as 1385.62 written as 1.386 × 10^3

	Indiana Academic Standard for Eighth Grade Mathematics – Adopted April 2014	Highlighted Vocabulary Words from the Standard Defined
	Algebra and Functions	
MA.8.AF.1:	Solve linear equations with rational number coefficients fluently, including equations whose solutions require expanding expressions using the distributive property and collecting like terms. Represent real-world problems using linear equations and inequalities in one variable and solve such problems.	Coefficient – the numerical factor of a term that contains a variable. Fluently – efficient and accurate
MA.8.AF.4	Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear, has a maximum or minimum value). Sketch a graph that exhibits the qualitative features of a function that has been verbally described.	Qualitative – descriptive information not based on numbers.
MA.8.AF.6	Construct a function to model a linear relationship between two quantities given a verbal description, table of values, or graph. Recognize in $y = mx + b$ that m is the slope (rate of change) and b is the y-intercept of the graph, and describe the meaning of each in the context of a problem.	Slope - the ratio of the vertical change to the horizontal change. Y-intercept - the y-coordinate of the point where the graph crosses the y-axis.

	Indiana Academic Standard for Eighth Grade Mathematics – Adopted April 2014	Highlighted Vocabulary Words from the Standard Defined
	Measurement and Geometry	
MA.8.GM.4	Understand that a two-dimensional figure is congruent to another if the second can be obtained from the first by a sequence of rotations, reflections, and translations. Describe a sequence that exhibits the congruence between two given congruent figures.	Congruent - congruent figures have the same size and shape.
	Data Analysis, Statistics and Probability	
MA.8.DSP.1	Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantitative variables. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.	Bivariate - a set of data that has two variables. Clustering - when data seems to be "gathered" around a particular value. Outlier - a value that lies “outside" (is much smaller or larger than) most of the other values in a set of data. Positive association - as one variable increases, the other variable increases. Negative association - as one variable decreases, the other variable decreases.

Table 4

Assessment Vocabulary Studied in the Intervention

Key Word or Phrase	Example of Use
Best	“Which statement best describes the two shapes?”
Choose	“Choose two fractions that are greater than 0.50.”
Complete	“Complete the table by filling in the missing numbers.”
Define the variable	Students should be able to provide a precise description of a variable used in an equation.
Enter	“Enter the product. 214 x 12”
Greatest	“What is the greatest number of hats Sarah can buy?”
Identify	“Identify all errors in Jenna’s work.”
In All	“How much money does Amy spend in all?”
More / Fewer	“How many more stickers does Jimmy need to complete his collection?”
Plot	“Plot an X on the line plot to represent Eric’s data.”
Represent	“Represent 0.20 as a fraction.”
Select	“Select the shape(s) that match the given attributes.”
Shade	“Shade squares in the grid that represent the given fraction.”
Show All Work	Students should be able to show all work needed to solve problems.
Solve / Evaluate	Solve. 145 + 82
Use Words, Numbers, and/or Symbols…	“Use words, numbers, and/or symbols to support your answer.”

CHAPTER 4

RESULTS

The purpose of this study was to determine if there is a significant effect from a directed study of mathematics vocabulary on high-stakes standardized mathematical questions for eighth-grade students enrolled in pre-algebra in a rural school in southern Indiana. The study took place during the 2015-2016 school year, and I quantitatively examined student performance on pretests and posttests created using Acuity. The control teacher and I administered the pretest in August 2016 and the posttest in December 2016. The independent variable was the treatment, a directed study of mathematics vocabulary designed by me, which is described in detail later in this chapter. The dependent variable was the posttest score and the statistical analysis was adjusted by each student's pretest score. I based the curriculum used by both the control group teacher and the treatment group teacher on the content of the 2014 Indiana Academic Standards for Mathematics for Grade 8 (IDOE, 2015a).

Quantitative Research Question and Hypothesis

The research questions that I sought to answer were as follows.

1. Does a directed study of mathematics vocabulary significantly affect student performance levels on standardized mathematical questions?
2. Will the strategies used in this study significantly affect student performance levels on standardized mathematical questions?

To determine a significant effect, I would have to reject the following null hypotheses:

$H1_0$: A directed study of mathematics vocabulary has no significant effect on student performance levels on standardized mathematical questions.

$H2_0$: The strategies used in this directed study of mathematics vocabulary have no significant effect on student performance levels on standardized mathematical questions.

I used the same outcomes data to answer both of these questions; however, the second question's answer was additionally augmented by my review of the vocabulary journals, my interview/observations of the host teacher, and field notes.

Study Variables

The independent variable was the implementation of the intervention (directed study of mathematics versus no directed study). Those students from the treatment school received a directed study of mathematics, and those from the control school did not participate in the directed study. Table 5 shows a summary of the 89 students in the study.

Table 5

Summary of Treatment and Control Groups

	n	Percent
Control Group	37	41.6
Treatment Group	52	58.4

The dependent variable used for analysis was the posttest score from the 89 students. I calculated the test scores by adding up the total number of correct responses of 19 questions for each participant. If a student correctly identified the mathematics vocabulary term, then that item was correct.

Table 6 shows pretest scores by control and treatment groups. Because pretest scores in the treatment group were slightly lower than those in the control group, I used a repeated measures ANCOVA to analyze the difference in posttest scores between control and treatment groups, while controlling for pretest scores.

Table 6

Summary of Pretest Scores by Control and Treatment Groups

	Control		Treatment	
	Mean	SD	Mean	SD
Pretest	6.49	2.35	6.23	2.45
Posttest	8.46	3.41	11.33	3.33

Results

Research Question 1 asked, "Does a directed study of mathematics vocabulary significantly affect student performance levels on standardized mathematical questions?" To assess this question, I performed a repeated measures ANCOVA to analyze scores from a mathematics vocabulary posttest for each participant, by the treatment and control groups, while controlling for student pretests scores. Results of the analysis showed that there was a significant difference in posttest scores between the treatment and control groups, after adjusting for pretest scores, $F = 20.12$, $p < 0.0001$. Specifically, students in the treatment group had significantly higher posttest scores ($M = 11.33$, $SD = 3.33$) than those in the control group ($M = 8.46$, $SD = 3.41$). I therefore rejected the null hypothesis, concluding that a directed study of mathematics vocabulary has a significant effect on student performance levels on standardized mathematical questions.

Additional Analyses

One of the components in the treatment was students keeping a vocabulary journal. Each student in the treatment group used the vocabulary journal to facilitate an introduction to each vocabulary term by determining and recording what the student already knew about the term.

After the term was introduced, students were asked to give examples in their journals. The class would come to a consensus, through discussion and use of the text and glossary, on the OML definition for the vocabulary term being studied; the students would then record it in their vocabulary journals. After repeating this process for several terms, students were given time to create illustrations for each term. This was done in small groups through collaboration and use of the Internet. I noted that students generally complained about being asked to write in their vocabulary journals and rushed through their journal work as quickly as they could. They had to constantly be reminded to complete them and to rate their understanding of the word in the space provided at the top of each page. Many commented during journal activities that they did not know what to write or draw. I perceived that the students did not like this activity because there was no right or wrong answer, and it required a higher level of thinking about the term. Overall, finding time in the classroom to complete the journals was a challenge.

I performed two additional analyses to observe the association between student journal entries and pretest and posttest scores in the treatment group. First, in each journal entry, students rated their understanding of the vocabulary term. Given this, I created a journal score by adding up all 4 responses for each student, and then creating a total understanding score from the journal entries. Journal scores to measure understanding could range from 0 to 19, with higher scores indicating a deeper understanding of mathematics vocabulary. For the treatment group, average journal/understanding scores ranged from 0 to 17, with an average score of 7.21 (*SD* = 5.31). The median journal/understanding score was 8.0. Both the average and median journal/understanding scores were below the midpoint of 8.5.

I then compared these journal/understanding scores to the pretest and posttest scores (Table 7) to determine if there was a significant association between students' understanding of mathematics vocabulary and their scores on the pretest and posttest. To decide if the journal/understanding scores were associated with pretest and posttest scores, I performed a Pearson's correlation analysis. Researchers typically use Pearson's correlation to measure the association or linear dependence between two continuous variables. For this study, the continuous variables were journal/understanding score and pretest and posttest scores. The results of the correlation analysis showed that the journal/understanding scores were not significantly associated with the pretest scores, r = -0.03, p = 0.820, nor were they associated with the posttest scores, r = 0.23, p = 0.103.

Second, I rated each student's entry using sections from the rubric (Figure 8). These two sections from the rubric are shown in Figure 12. I paid close attention to students' understanding of mathematical concepts and their use of OML. Using a scale where a numeric score of 4 is high and 1 is low, I matched student vocabulary journal scores with the quantitative scores from the pretests and posttests, searching for any patterns that might appear. I used a score of 0 when the student had no journal entry for the term being evaluated.

Mathematical Concepts	Explanation shows complete understanding of the mathematical concepts.	Explanation shows substantial understanding of the mathematical concepts.	Explanation shows some understanding of the mathematical concepts.	Explanation shows very limited understanding of the underlying concepts.
Official Mathematics Language (OML)	OML definitions are clear and 90-100% are accurate.	OML definitions are clear and almost all (85-89%) are accurate.	OML definitions are mostly clear and (75-84%) are accurate.	More than 75% of the OML definitions are unclear and inaccurate.

Figure 12. Two sections from rubric for math vocabulary journal.

Table 7

Summary of Journal Scores for Each Mathematical Concept

	0		1		2		3		4		Number Correct Pretest	Number Correct Posttest
	N	%	*N*	%	*N*	%	*N*	%	*N*	%		
Bivariate Data	1	1.90	21	40.40	16	30.80	10	19.20	4	7.70	31	38
Constant of Proportionality	1	1.90	3	5.80	6	11.50	21	40.40	21	4.04	8	29
Input	4	7.70	17	32.70	14	21.10	11	21.20	6	11.50	15	30
Irrational Number	0	0.00	0	0.00	4	7.70	23	44.20	25	48.10	21	40
Linear Equation	6	11.50	11	21.20	13	25.00	12	23.10	10	19.20	23	34
Output	3	5.80	19	36.50	15	28.80	10	19.20	5	9.60	17	31
Proportional Relationship	1	1.90	3	5.80	8	15.40	17	32.70	23	44.20	21	26
Real Number	4	7.70	3	5.80	10	19.20	17	32.70	18	34.60	14	26
Repeating Decimal	0	0.00	0	0.00	4	7.70	22	42.30	26	50.00	7	16
Scatterplot	6	11.50	15	28.80	17	32.70	13	25.00	0	0.00	7	10
Scientific Notation	11	21.20	3	5.80	3	5.80	17	32.70	18	34.60	5	37
Slope	2	3.80	7	13.50	18	34.60	14	26.90	10	19.20	16	33
Slope Intercept Form Q1	8	15.40	10	19.20	11	21.20	10	19.20	13	25.00	16	34
Slope Intercept Form Q2	8	15.40	10	19.20	11	21.20	10	19.20	13	25.00	14	38
Square Root Q1	10	19.20	8	15.40	7	13.50	16	30.80	11	21.10	39	48
Square Root Q2	10	19.20	8	15.40	7	13.50	16	30.80	11	21.10	14	23
Terminating Decimal	1	1.90	1	1.90	4	7.70	23	44.20	23	44.20	25	35
Y-Intercept Q1	0	0.00	1	1.90	3	5.80	23	44.20	25	48.10	14	20
Y-Intercept Q2	8	15.40	16	30.80	11	21.20	9	17.30	8	15.40	29	35

I performed this second analysis to observe the association between the journal scores of the students and the pretest and posttest scores in the treatment group. When scoring the journal entries, I provided a response score of 4, which indicated that the student's journal entry demonstrated that he or she understood a specific mathematics term. Given this, I created a journal score by adding up all 4 responses for each student, creating a total understanding score from the journal entries. Journal scores to measure understanding could range from 0 to 19, with higher scores indicating a deeper understanding of mathematics vocabulary. For the treatment group, average journal/understanding scores ranged from 0 to 13, with an average score of 5.44 (*SD* = 3.50). The median journal/understanding score was 5. Both the average and median journal/understanding scores were below the midpoint score of 8.5.

As the distribution of scores from Table 7 shows, there are relatively low numbers of students scoring a 0 or 1 for most of the mathematical concepts with the exception of scientific notation, slope intercept Form Q 1 & 2, square roots Q 1 & 2, and Y-intercept Q 2. When the students took the posttest, however, their scores improved—demonstrating that they did have understanding. This raises the question of why the journal/understanding scores were so low for these concepts, whether the students were not given enough time to complete their journals, whether the class did a good job of putting these concepts into words. It could be because all were new concepts to the students, and they had little background knowledge for these new ideas. Perhaps there was another aspect of the treatment that allowed the students to perform higher on the test while rating their understanding at the low level. It is possible to target something that should be changed instructionally in terms of improving the various portions of the intervention. These issues are considered further in Chapter 5.

By contrast, distribution of scores for irrational numbers, proportional relationship, real number, repeating decimal, and terminating decimal were all heavily weighted on the 3-4 end of scale. Repeating decimal and terminating decimal are both concepts that are easily grasped by students and have been studied by them in previous years. I provided a graphic organizer for the study of irrational and real numbers in addition to the vocabulary journal, which could have increased student understanding. *Proportional relationship* was a concept that was emphasized and reviewed in a 3-week unit that included graphing of equations, which the students seemed to enjoy.

I compared the journal/understanding scores to the pretest and posttest scores to determine if there was a significant association between students' understanding of mathematics vocabulary and their scores on the pretest and posttests. To decide if the journal/understanding scores were associated with pretest and posttest scores, I performed a Pearson's correlation analysis. For this analysis, the continuous variables were journal/understanding score and pretest and posttest scores. The results of the correlation analysis showed that the journal/understanding scores given by the students in their vocabulary journals were not significantly associated with the pretest scores, $r = -0.04$, $p = 0.756$. The posttest scores were significantly associated with journal/understanding scores, $r = 0.38$, $p = 0.005$. Specifically, higher posttest scores were associated with higher journal/understanding scores, with a moderate positive correlation.

In addition to the classroom observations of the control teacher during the study, an additional component of the qualitative portion of the study was an interview with the control teacher at the completion of the study in December 2016. The questions used for the interview can be found in Appendix D. The results of the classroom observations revealed that both the control teacher, and myself as the experimental teacher, had very similar styles of teaching. We each began class with an opening activity that students began when the bell signaled to start class, usually reviewing the previous day's material. We each taught from the front of the room using an interactive whiteboard as we presented the lesson and engaged the students. We both applied background knowledge as new material was introduced. Students were questioned and engaged by the teacher and required to demonstrate understanding by using a variety of methods including a short quiz, practice problems, classroom response systems, or writing responses on individual whiteboards. The study of new vocabulary words in the control classroom included acknowledgement of the new term, a verbal definition, and then using the word in the lesson. At times, if it was a vocabulary term that had already been studied, the control teacher would say something like, "Remember, we talked about this last week." In contrast, in the experimental classroom, new terms were introduced as described in the intervention for this study. In the interview of the control teacher after the conclusion of the study (see Appendix D for questions used), the control teacher stated that she felt that it is important for students to learn mathematical vocabulary, but she did not use a specific routine for teaching vocabulary. During my eight classroom observations I found this to be true. She commented that she wanted to have a word wall but had not yet started one even though the second semester would soon begin.

Summary

The main purpose of this study was to determine if there was a significant effect from a directed study of mathematics vocabulary on high-stakes standardized mathematical questions for eighth-grade students enrolled in pre-algebra in a rural school in southern Indiana. The results of the statistical analyses showed that students in the treatment group had significantly higher posttest scores than those in the control group. The results of an additional analysis showed that when the students rated their own journal/understanding of the terms in their vocabulary journals, there was no significant correlation between their own rating and their posttest scores; however, higher posttest scores were associated with higher journal/understanding scores given by me, demonstrating a moderate positive correlation.

CHAPTER 5

DISCUSSION

Due to the influence of Common Core and College and Career-Readiness Standards, the Indiana State Board of Education approved adopting a new set of academic standards for Language Arts and Mathematics (IDOE, 2015b). Language skills have become increasingly important in mathematics classrooms. The NCTM includes communication as a process strand, requiring that students, in oral and written formats, explain their problem-solving strategies both in the classroom and on high-stakes tests (NCTM, 2000). Indiana Academic Standards outline what students should know and be able to do in Math and English at a certain grade or level. Students are required to demonstrate their acquisition of these skills and knowledge along with their ability to apply what they have learned when taking the ISTEP+ (IDOE, 2015b). Passing the ISTEP+ in Language Arts and Mathematics means that students are on the path to becoming college and career-ready (Indiana Department of Education, 2015b). By way of communicating this to Indiana constituencies, the authors of the IDOE website asserted that students who are successful in mastering the new Indiana Academic Standards for Math and English/Language Arts by the time they graduate from high school will be prepared to directly go into the workplace or into a postsecondary educational opportunity without the need for remediation (IDOE, 2015b).

The results of high-stakes tests such as ISTEP+ have many implications for students. Tests such as these determine students' academic opportunities, where and how students are placed in school programs, and can impact a child's self-esteem. Due to the implementation of Indiana's new mathematics standards, there are new assessment demands. Brenneman (2014) cited concerns such as writing an assessment that measures depth of understanding instead of breadth, designing performance tasks that challenge students to apply mathematical knowledge through multiple standards simultaneously, and creating assessments that control cultural biases.

Students must not only recognize a mathematical term, but must also understand the concepts and functional processes underlying the term sufficiently to employ the correct mathematical processes the term may require the student to know or perform (Burns, 2006). The "depth and breadth of a child's mathematical vocabulary is more likely than ever to influence a child's success in math" (Pierce & Fontaine, 2009, p. 239). The language of mathematics consists of content and process (Kenney et al., 2006). The content includes nouns such as numbers, "measurements, shapes, spaces, functions, patterns, data, and arrangements," (Kenney et al., 2006, p. 2) while verbs such as compute, identify, solve, and simplify represent actions that are performed during the processing of these mathematical objects. Although studying the language of mathematics may be like studying a foreign language, the two are different; the learning of the language of mathematics is done so that one can learn concepts, let the notion take shape in the mind, and then be used to communicate mathematical ideas. This requires the teaching of both ideas and vocabulary (Usiskin, 1996).

Ely et al. (2014) posited that the language of mathematics not only presents unique challenges for students in the classroom, it can challenge teachers as well. The authors contended that part of the problem is that many teachers lack a solid knowledgebase for effective instructional strategies that promote understanding and accuracy of use of mathematical vocabulary and language. Ely et al. (2014) stated, "The field of teacher preparation needs programs of research that specify methods to develop engaged knowledge of vocabulary instruction and improve teacher use of effective vocabulary practices" (p. 36). I designed the current study to determine whether a set of interventions created to promote understanding of mathematical vocabulary would affect student scores on standardized mathematical questions, thereby adding to the knowledgebase of effective vocabulary instruction and practices. The purpose of this study was to determine whether there is a significant effect from a directed study of mathematics vocabulary on high-stakes standardized mathematical questions for eighth-grade students enrolled in pre-algebra in a rural school in southern Indiana. The following questions guided the study:

1. Does a directed study of mathematics vocabulary significantly affect student performance levels on standardized mathematical questions?
2. Will the strategies used in this study significantly affect student performance levels on standardized mathematical questions?

I used a mixed methods approach to gather both quantitative and qualitative data. I designed a quasi-experimental study employing a repeated measures ANCOVA to analyze the scores from a mathematics vocabulary pretest and posttest for each participant. The population for the study was eighth-grade pre-algebra students from two different middle schools in southern Indiana. I chose ANCOVA for the statistical test to assure homogeneity when comparing the means of the pretest and posttest. The independent variable was the treatment, a directed study of mathematics vocabulary designed by me, which is described in detail later in this chapter. The dependent variable was the posttest score. For the qualitative data, I evaluated the students' vocabulary journals.

Results of the study showed that there was a significant difference in the posttest scores between the control and treatment groups, $F = 20.12$, $p < 0.0001$. The treatment group had significantly higher posttest mean scores ($M = 11.33$, $SD = 3.33$) compared to those of the control group (M = 8.46, SD = 3.41). With this, I rejected the null hypothesis, as the results confirm that a directed study of mathematics vocabulary has a significant effect on student performance levels on standardized mathematical questions.

I performed a Pearson correlation analysis to identify the association between student journal entries and pretest and posttest scores. The results showed that the journal/understanding scores were not significantly associated with the pretest scores, r = -0.03, p = 0.820, nor were they associated with the posttest scores, r = 0.23, p = 0.103. Another analysis was done by rating the student vocabulary journals and matching this with the quantitative scores from pretests and posttests to identify any pattern. I performed this analysis to observe the association between the journal scores given to the students by me and the pretest and posttest scores in the treatment group. After comparing the journal/understanding scores to pretest and posttest scores to identify if there is a significant association between a student's understanding of mathematics vocabulary and their pretest and posttest scores, results showed that journal/understanding scores given to students in their vocabulary journals were not significantly associated with pretest scores, r = -0.04, p = 0.756, but posttest scores were significantly associated with journal/understanding scores assigned by the teacher, r = 0.38, p = 0.005. Higher posttest scores were associated with higher journal/understanding scores, with a moderately positive correlation.

Vocabulary Strategies Used in the Classroom

During this study, a typical 50-minute classroom included attendance, a question-and-answer period between students and teacher concerning the previous night's homework, and the presentation of new material. Here, I focused on what was done in the classroom pertaining to the study of mathematics vocabulary, keeping in mind that this was only a part of what was taking place in the classroom on a daily and weekly basis.

A variety of methods were used for introducing a new vocabulary term at the beginning of a lesson. These included showing a video, discussing a picture or a photo, talking about a real-world situation, or using an introductory vocabulary activity (see further detail under The Intervention in Chapter 2). These were created working from an assertion by Rubenstein and Thompson (2002): “A major premise of all strategies is to connect new terms or phrases to ideas children already know” (p. 108). Using these and similar activities was to draw the students’ interest and attention along with providing an opportunity for assessing background knowledge and creating a vision of what the lesson was targeting. After the introduction of a new vocabulary term and lesson concept, students were usually asked to turn to the term in their vocabulary journal where they were instructed to enter an answer in the box, “What do I already know about this word?” Ideas were then shared with a partner, in a small group, or in a class discussion. The class was then referred to the text discussion of the term to see if what they already knew what was mentioned in the text. The class then viewed, studied, and discussed examples during the lesson and students were asked to record notes in their vocabulary journals to help them remember the new term. As a part of the classroom routine, homework would be assigned and students would begin working on it in class. When students had similar questions, further explanation and discussion would take place.

At a later time, usually on a Friday in class, the vocabulary for the week would be reviewed again by playing different vocabulary games. The games played, described in The Intervention section of Chapter 2, included Classroom Password, Charades, Vocabulary Jeopardy, an online game called Rational and Irrational Numbers, Vocabulary Treasure Hunt, and “I have, who has?” The atmosphere in the classroom always livened when games were played and interest and motivation were sparked. Games gave students the opportunity to interact with the words in a different way that necessitated thinking about the word and keeping its meaning in their thoughts.

During the following weeks, to facilitate review and memorization of the term, students were asked to draw illustrations of the word in their vocabulary journals. To get ideas, students were allowed to search the Internet and their textbooks. At times, the teacher might present charts, graphs, or graphic organizers that students could record in their journals. Two of the students' favorites are shown in Figure 13.

Cube root

Input/output

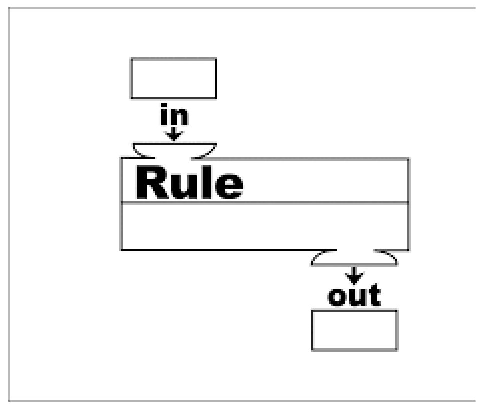


Figure 13. Sample illustrations from the students' vocabulary journals.

The OML definition was usually the last entry for each term in the vocabulary journal. This definition could be copied from the explanation of the word in the student's textbook, or from its glossary, or from a definition agreed upon following one of the classroom discussions. OML definitions of words served as a reference for the students when needed and were used for review before playing vocabulary games on Fridays.

An analysis of each of the vocabulary words used in the treatment follows. The pretest and posttest scores are given, the treatment(s) used for the term is stated, and any additional observations and conclusions about the treatment of the word are discussed.

1. Vocabulary Term: Bivariate data

a. The number of correct answers on the pretest was 31.

b. The number of correct answers on the posttest was 38.

c. Bivariate data was a new term introduced in eighth-grade mathematics.

d. The meaning of the prefix *bi* was discussed as meaning two and students called out words having *bi* in them such as bicycle, biannual, and binoculars, which helped them make a connection to background knowledge.

e. I found that students were familiar with the term *variable,* which helped them to decode the term bivariate to mean involving two variables.

2. Vocabulary Term: Constant of Proportionality

a. The number of correct answers on the pretest was 8.

b. The number of correct answers on the posttest was 29.

c. This term was introduced during the study of proportional relationships defined as the relationship between two quantities in which the ratio of one quantity to the other quantity is constant. Students learned that a proportional relationship can be written in the equation forms $y = kx$ or $= \frac{y}{x}$, where k is a number referred to as the constant of proportionality.

d. Throughout the study of proportional relationships, students were repeatedly required refer to *k* as the constant of proportionality.

e. I found that the constant review of constant of proportionality helped the students remember the term.

3. Vocabulary Term: Input

a. The number of correct answers on the pretest was 15.

b. The number of correct answers on the posttest was 30.

c. I found that as the class discussed independent variables, students connected input with the variable *x* as the value that was substituted into a function.

4. Vocabulary Term: Irrational Number

   a. The number of correct answers on the pretest was 21.

   b. The number of correct answers on the posttest was 40.

   c. The definition, “A number that cannot be expressed as a ratio of two integers or as a repeating or terminating decimal” was used in the Word Hunt game described in Chapter 2, The Intervention, under Step 6.

   d. Students played the online game Rational and Irrational Numbers on three separate occasions during the term.

   e. In groups of four, students were given index cards and asked to create flashcards putting a number on one side and the appropriate word rational or irrational on the other side. They traded cards with a nearby group and checked each other’s cards. The cards were then placed in a basket and the teacher drew a card and wrote the number on the Promethean Board. Students recorded Rational or Irrational on their individual white board. If a student had an incorrect answer, then the teacher would ask the class to discuss the correct response. If everyone was correct, the class would be praised and I would go to the next number.

   f. Every day, during the course of class discussions, students would be asked to identify randomly if a number was rational or irrational.

   g. I found that this is a difficult skill for students to master but they improved with constant practice.

5. Vocabulary Term: Linear Equation

   a. The number of correct answers on the pretest was 23.

b. The number of correct answers on the posttest was 34.

c. Students were introduced to the word linear, repeatedly being reminded by me in class that the word *line* was found in *linear* and the graph of a linear equation was always a straight line.

d. I found that as linear equations were frequently used in class, by discussing, identifying, and graphing linear equations, students became more proficient at explaining why these equations were called linear.

6. Vocabulary Term: Output

   a. The number of correct answers on the pretest was 17.

   b. The number of correct answers on the posttest was 31.

   c. When students were asked to illustrate *output*, many of them chose to use the same figure used for *input*. As the class discussed dependent variables, students connected output with the variable y as the "answer" when x was substituted into$y = mx + b$.

   d. I found that using a chart to identify the x and y values when discussing equations, gave students a better understanding of input and output.

7. Vocabulary Term: Proportional Relationship

   a. The number of correct answers on the pretest was 21.

   b. The number of correct answers on the posttest was 26.

   c. Proportional relationships were represented as tables, graphs, equations, and used in real-world problems.

   d. I found that the term proportional relationship was a difficult term for students to grasp. By demonstrating that it can be described by an equation of the form $y = kx$, where k is a number called the constant of proportionality, students could then identify proportional relationships with more accuracy.

8. Vocabulary Term: Real Number
    a. The number of correct answers on the pretest was 14.
    b. The number of correct answers on the posttest was 26.
    c. The definition, “A rational or irrational number” was used in the Word Hunt game described in Chapter 2, The Intervention, under Step 6.
    d. I found that when students were given a graphic organizer to study the classification of real numbers, this aided them in learning the meaning of a real number.
9. Vocabulary Term: Repeating Decimal
    a. The number of correct answers on the pretest was 7.
    b. The number of correct answers on the posttest was 16.
    c. The definition, “A decimal in which one or more digits repeat infinitely” was used in the Word Hunt game described in Chapter 2, The Intervention, under Step 6.
    d. I found that students often confused irrational numbers such as 0.12122122212222 . . . with repeating decimals which have a block of one or more digits that repeat indefinitely. This must be reviewed repeatedly to remind students of this concept. The ellipses are bothersome and students confuse irrational numbers with ellipses with rational numbers that have ellipses.
10. Vocabulary Term: Scatterplot
    a. The number of correct answers on the pretest was 7.
    b. The number of correct answers on the posttest was 10.

c. We worked in class on problems using scatterplots but for some reason, the class did not record an OML definition for the term.

d. I realize now that I should have had students give a formal definition of scatterplots and worked with scatterplots in a more formal lesson.

11. Vocabulary Term: Scientific Notation

a. The number of correct answers on the pretest was 5.

b. The number of correct answers on the posttest was 37.

c. The definition, "A method of writing very large or very small numbers by using powers of 10" was used in the Word Hunt game described in Chapter 2, The Intervention, under Step 6.

d. Students practiced writing numbers in scientific notation and changing numbers written in scientific notation into standard form.

e. I found that the work we did with scientific notation was effective demonstrated by an increase from 5 correct answers on the pretest to 37 correct answers on the posttest.

12. Vocabulary Term: Slope

a. The number of correct answers on the pretest was 16.

b. The number of correct answers on the posttest was 33.

c. Slope was introduced as a rate of change and in different lessons, including the ratio of the amount of change in the dependent variable, or output, to the amount of change in the independent variable, or input. Slope was defined as rate of change, the rise over the run and the change in *y* over the change in *x*.

d. I found that having students investigate slope in a variety of ways using tables, graphs, formulas, unit rates, and real-world problems aided students in identifying and applying the concept of slope.

13. Vocabulary Term: Slope-Intercept Form Question 1

a. The number of correct answers on the pretest was 16.

b. The number of correct answers on the posttest was 34.

c. Students were introduced to slope-intercept form and were required to memorize the equation $y = mx + b$.

d. I found that having students memorized the equation $y = mx + b$ made it possible for them to identify the correct matching item for slope-intercept form.

14. Vocabulary Term: Slope-Intercept Form Question 2

a. The number of correct answers on the pretest was 14.

b. The number of correct answers on the posttest was 38.

c. Students were required to graph linear equations using slope-intercept form.

d. I found that because students had already defined slope, this made it easier for them to identify the y-intercept.

15. Vocabulary Term: Square Root Question 1

a. The number of correct answers on the pretest was 39.

b. The number of correct answers on the posttest was 48.

c. The definition, “A number that is multiplied by itself to form a product is called a square root of that product” was used in the Word Hunt game described in Chapter 2, The Intervention, under Step 6.

d. I found that students often confuse the square of a number with the square root of a number. This needs to be emphasized to the students as they work with square root.

16. Vocabulary Term: Square Root Question 2

  a. The number of correct answers on the pretest was 14.

  b. The number of correct answers on the posttest was 23.

  c. The definition, “A number that is multiplied by itself to form a product is called a square root of that product” was used in the Word Hunt game described in Chapter 2, The Intervention, under Step 6.

  d. I found that just because a student can find the square root of a whole number, it does not necessarily follow that the student can identify the square root of a fraction.

17. Vocabulary Term: Terminating Decimal

  a. The number of correct answers on the pretest was 25.

  b. The number of correct answers on the posttest was 35.

  c. The definition, “A decimal number that ends, or terminates” was used in the Word Hunt game described in Chapter 2, The Intervention, under Step 6.

  d. I found that because students had background knowledge of things that terminate, such as the movie *The Terminator* or terminating a subscription to an online service, it was easier for them to remember the definition of a terminating decimal.

18. Vocabulary Term: Y-Intercept Question 1

  a. The number of correct answers on the pretest was 14.

  b. The number of correct answers on the posttest was 20.

c. Each time an equation was graphed in a lesson, students were asked to identify the y-coordinate of the point where the graph of the line crossed the y-axis.

d. I found that students were able to identify the slope and the y-intercept to aid them when graphing an equation in the form $y = mx + b$.

19. Vocabulary Term: Y-Intercept Question 2

a. The number of correct answers on the pretest was 29.

b. The number of correct answers on the posttest was 35.

c. Each time an equation was graphed in a lesson, students were asked to identify the y-coordinate of the point where the graph of the line crossed the y-axis.

d. I found that when students had memorized the equation $y = mx + b$, they were able to identify the y-intercept.

As evidenced in Table 7 in the preceding chapter, terms having the greatest growth from pretest to posttest were constant of proportionality (increase of 21), irrational number (increase of 19), scientific notation (increase of 32), slope (increase of 17), slope intercept form Q1 (increase of 18), and slope intercept form Q2 (increase of 24). These vocabulary terms had been newly introduced to students in grade eight so it makes sense that these terms would show the highest gain. Simple repetition alone was not sufficient without the motivating activities used to introduce and help students gain ownership of the terms. As illustrated above, when these concepts were being taught, the vocabulary was reviewed daily and multiple ways of interacting with the term were employed. Authors such as Pierce and Fontaine (2009), Harmon et al. (2005), Rubenstein and Thompson (2002), Smith and Angotti (2012), who study mathematical vocabulary, highly recommend these practices when teaching mathematics vocabulary. I would continue to carry out these methods to help students increase their understanding.

In the classroom during the study, I asked students to use OML when discussing math, for example, if the class were studying a proportional relationship such as $y = kx$, they referred to k as the constant of proportionality. In my classroom in the past, I would not insist on using OML; however, as part of the intervention, I insisted that both students and teacher use the proper terminology. Using the proper terms on a daily basis helped the students with their mathematics communication skills and helped them improve their mathematical vocabulary daily. I recommend that this practice be continued in the classroom.

Using vocabulary games is another aspect of the study that I would continue to do in the classroom. Nguyen and Khuat (2003) designed a study to learn if games help students effectively learn vocabulary. The authors offered that games bring relaxation and fun to the classroom helping improve retention of new words. They also submitted that games usually involve competition and keep the interest of the learners. Nguyen and Khuat continued to commend the use of games, stating that they often bring real-world context into the classroom, which provides students an opportunity to communicate with the new vocabulary. It is highly motivating for the students and enjoyable for the teacher to watch how the students interact with the vocabulary in a fun and challenging way. Students looked forward to Fridays because they knew it was game day and the competition not only aided learning, but made the class dynamic. One of the computer games that was especially helpful for students when identifying rational and irrational numbers was the Rational and Irrational Numbers Game (MATH-PLAY, n.d.). In this game, rational and irrational numbers scroll across the computer screen and students make quick decisions how to classify each number and drag it into the proper container on the screen. Students were challenged to get a perfect score of 200, and most were motivated to keep trying until they reached it. Games played in the classroom are described in Chapter 2, The Intervention, Step 6, and included Classroom Password, What is the question? (a Jeopardy!-type game), Vocabulary Charades, I have - who has?, Vocabulary Word Hunt, and Hangman. Game-day-Fridays likely contributed to advancements in understanding as these games provided a unique and challenging way for students to interact with the vocabulary terms.

I would continue to use vocabulary journals in the classroom. I would modify the journal to include a section for root words and etymology as illustrated in Figure 14. As demonstrated in the bullet section of Vocabulary Strategies Used in the Classroom, words such as bivariate, linear, repeating, scientific notation, slope, and terminating, etymology and root words helped develop a deeper understanding of the vocabulary terms. Origins of words can help students make connections. Rubenstein and Thompson (2002) explained when teachers share with students the "'words behind the words' they connect terms that sound 'foreign' to words they already know . . .. For example percent means literally 'for each hundred,' from which we derive 'divided by 100'; or 'hundredths'" (p. 108). Because most students are familiar with our system of money, they can relate the fact that there are 100 *cents* in one dollar. Topics such as these would come up in classroom discussions of the vocabulary term and often lead to a Google search or sharing of background knowledge. These were of interest to the class, especially when the teacher and students Googled them together.

From my past experience in the mathematics classroom, I observed improved mathematical communication in the classroom and in student's written work. Other changes I would consider adding to the design of the intervention that could afford a positive impact on student performance include a word wall and student-made posters for vocabulary terms. However, as previously stated making time in the classroom for vocabulary activities is extremely challenging.

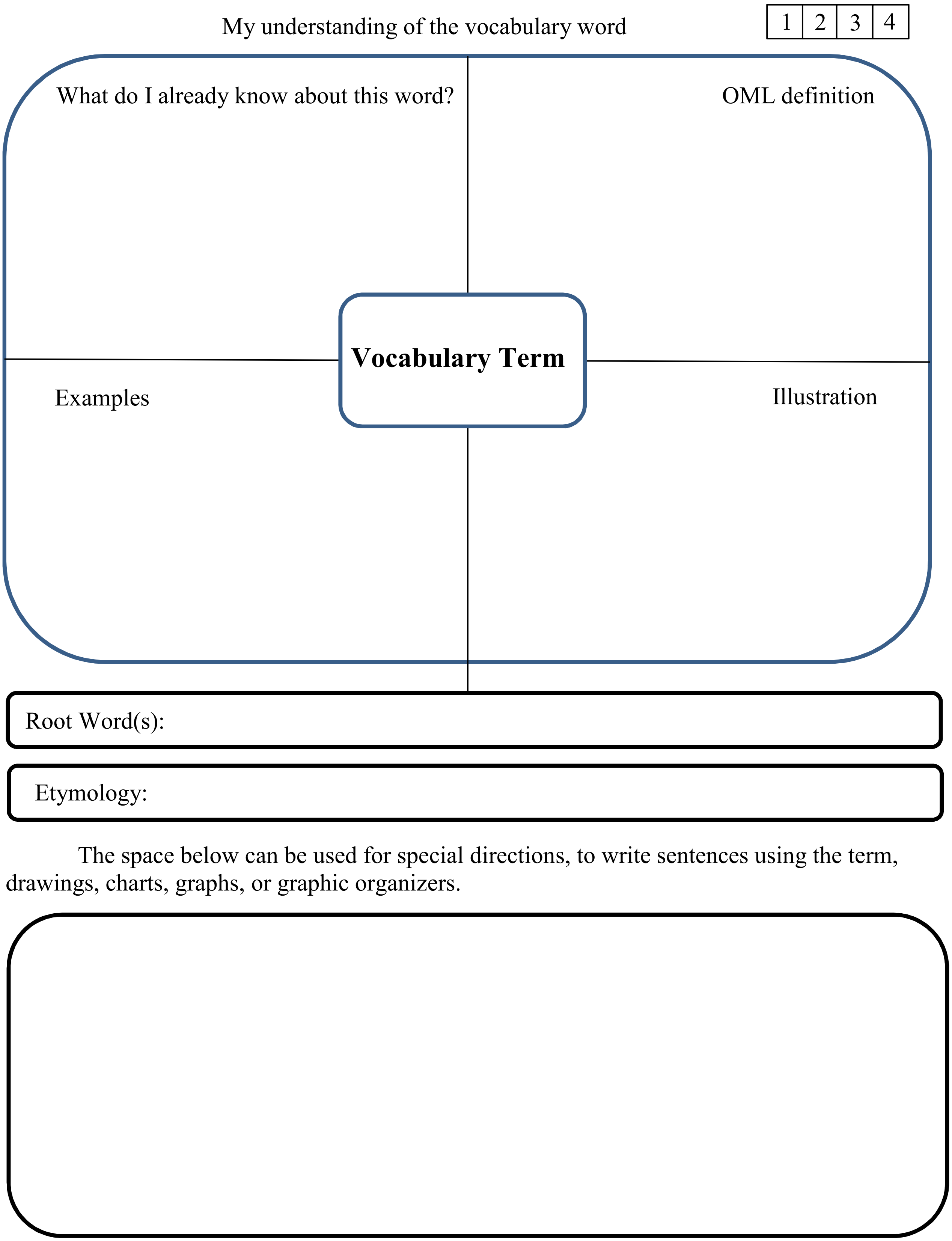


Figure 14. Revised vocabulary model for future study.

I would change the frequency of evaluating the vocabulary journals, which were not assessed until the end of the study in December. Ideally, I would do this more frequently, ensuring that students were completing the sections accurately, and rating their understanding of each vocabulary word as it changed over the course of interacting with the word. More time needs to be devoted in the classroom for discussion of what was placed in the vocabulary journals so that depth of understanding may increase. Realistically, however, time is at a premium and teachers often feel pressured to cover material for standardized testing, making it difficult for vocabulary study to be a priority to them.

Discussion of Findings

Results showed that there is a significant relationship between a directed study of mathematics vocabulary and student performance levels on standardized mathematical questions. Adams (2003) found that “a student’s ability to recognize and employ the formal definition is key to understanding and applying concepts when reading mathematical text” (p. 787). Similar literature on the topic has findings that support the results of this study. Vocabulary has been identified as important in understanding mathematics.

Mathematics texts are challenging to read because they have “more concepts per word, per sentence, and per paragraph than any other area” (Schell, 1982, p. 544). Mathematics language is rarely spoken at home and only in an educational setting. Usiskin (1996) provided an article about mathematics as a language. The purpose of his paper was to convince readers that mathematics has all the characteristics of a language and is “both oral and written and can be either informal or formal” (p. 232). Usiskin discussed how one’s native language is learned at an early age as part of the cultural environment and confirmed that “if the oral language is not learned before a certain age, then physical limitations may develop that make it difficult or even impossible to learn the language” (p. 238). This has implications for teaching the language of mathematics as early as possible, using OML vocabulary terms to avoid confusion for the student as he/she progresses through mathematics; e.g., call the shape a *square* not a *box*, call a shape a *rectangle*, not a *square* (if all four sides are not equal), call the top number of a fraction a *numerator*, and call the bottom number a *denominator*.

Harmon et al. (2005) provided an overview of current knowledge about vocabulary teaching and learning, understandings that influence learning across different disciplines. The authors discussed research on the teaching and learning of vocabulary in particular subject matter areas, including mathematics, social studies, and science. Harmon et al. explained,

> Vocabulary knowledge is closely linked to the difficulties many students experience in handling the demands of content textbooks . . .. [Teachers] would no doubt agree that a critical aspect of students' difficulty in understanding texts in their content area would be a lack of sufficient vocabulary knowledge . . .. The literature suggests that success in supporting vocabulary development in the content areas must consider students as word learners, the nature of content vocabulary, and the special features of effective vocabulary instruction. (p. 264)

A key component to understanding mathematics is learning the vocabulary (Miller, 1993). Many educators have agreed with Miller that "without an understanding of the vocabulary that is used routinely in mathematics instruction, textbooks, and word problems, students are handicapped in their efforts to learn mathematics" (p. 312). Ellerton and Clements (as cited in Miller, 1993) believed that "when someone actively links aspects of his or her physical and social environments with certain numerical, spatial, and logical concepts, a feeling of 'ownership' is often generated" (p. 313).

Hea-Jin and Herner-Patnode (2007) argued that "Without exposure to vocabulary, they [students] have a poor chance of successfully executing the required skill on state assessments.

Mathematical vocabulary helps students acquire the conceptual knowledge they need to understand age-appropriate concepts" (p. 122). Without learning mathematical vocabulary, students will be unable to communicate mathematically. Studies on vocabulary research provided evidence that direct vocabulary instruction should take place in all content areas (Allen, 1999). Direct vocabulary instruction supported learning of new concepts, deeper understanding of these concepts, and more productive communication. Blachowicz and Fisher (2002) stated that research and practice both supported the value of learning vocabulary in all content areas, in achieving the broader goal of acquiring content knowledge, and communicating within a discipline. The results of this study supported the need to understand mathematics through learning the vocabulary. The treatment given a group of students through providing them a directed study of mathematics vocabulary resulted in significantly higher student posttest scores.

Renne (2004) shared that studying vocabulary is meaningful and productive if students understand the concept that underlies the definition. To achieve this in a classroom setting, students need to be more familiar with new vocabulary words through discussing in class what the term means conceptually and operationally. The intervention as done in the current study is consistent with this approach, where the directed mathematics vocabulary study allows students to discuss the conceptual and operational meaning of the term in class.

Piaget and Inhelder (1969) hypothesized that assimilation and accommodation are important elements of a student's ability to make connections between old and new ideas and to construct and understand new mathematical ideas. Prior knowledge or conceptual understanding of the term and discussion should be at a concrete level. Supplying the definitions for study is not enough for them to really understand the meaning of the term. It is important that students are directed toward the conventional meaning of the word but also offered the chance to develop their own understanding of the term. This approach was again incorporated in the current study, which resulted in increased posttest scores. This outcome further strengthens findings that a direct study of vocabulary helps students perform better in mathematics examinations and supplements their understanding and learning of mathematics.

According to Lindquist (1996), “If we consider that mathematics is a language and that this language is best learned in a community of other learners, then it is easy to understand why there is a communication standard” (p. 2). There is a need to provide students the chance to use oral and written language in mathematics. “As in foreign-language acquisition, immersion in language usage is necessary to develop fluency” (Thompson & Rubenstein, 2000, p. 571). Students need the opportunity to talk about mathematics using the language of mathematics. One of the approaches in the intervention used in the current study was to allow students to write sentences using the vocabulary word, do drawings, make charts, or use a graphic organizer to deepen their understanding of the word. Aside from this, students also discussed among groups and within the class their definition of the new mathematics terms they identified. These intervention approaches are supportive of the needs Lindquist (1996) cited when learning mathematics vocabulary. The current intervention approach resulted in increased test scores for students in the treatment group. The findings reaffirm the importance and need for a directed vocabulary study to improve the knowledge of students in mathematics and to allow them to have a better understanding of the mathematical concepts and terms.

Thompson and Rubenstein (2000) recommended using a variety of strategies for teaching vocabulary, recognizing that there are different learning preferences which affect learner motivation and citing Gardner’s multiple intelligences, including oral, written, visual, and kinesthetic modes. In addition, Thompson and Rubenstein highly recommended that students should say aloud the words being learned, talk about their meanings, do writing activities that reinforce concepts and understanding, use visual representations (student-created or commercial products), and create activities that kinesthetically involve the student. It is important that students are given the chance to acquire the meaning of the vocabulary for them to develop the meaning of the words for himself/herself.

Miller (1993) argued that "to assist students in making connections between language and mathematical empowerment, teachers should implement strategies that give all students an opportunity to construct, in both receptive and expressive modes, the formal language of mathematics" (pp. 313-314). Vygotsky (1978) also had the same perception that there is a need to let individual learners regulate their own internal and external learnings with the assistance of the educators. This theorist encouraged letting students be independent in using tools of language—draw it, talk about it, write about it and even talk to themselves about it.

Hung (2002) conjectured, "the teacher plays a central role in steering and facilitating the discussions and externalizations made" (p. 197). During the class discussions, the teacher or other person who is more knowledgeable is needed to concretize and standardize the definitions of the vocabulary word so its wording is acceptable in the mathematics community. Teaching vocabulary terms in a specific manner is probably the most important action a teacher can make to provide students with the knowledge they need to succeed in school (Marzano & Pickering, 2005). "The language of mathematics is a vital tool for student learning. Therefore, enculturating students to the vocabulary, phrasing, and meanings of mathematical language is a dimension of instruction that needs specific attention" (Thompson & Rubenstein, 2000, p. 573). Approaches suggested by Marzano and Pickering (2005) included providing experiences such as a field trip, a virtual field trip, a guest speaker, telling a story that integrates the term, showing a video, providing images, asking students to research and perform a skit or pantomime, using current events, or creating a picture or drawing. Through increasing a student's vocabulary, he or she can broaden background knowledge that allows the student to relate new information which makes learning and understanding new concepts easier. An increase in vocabulary provides students the opportunity to be more independent needing less assistance from teachers to solve problems. Steele (1999) asserted,

> Communication plays an important role in helping children construct links between their informal, intuitive notions and the abstract language and symbolism of mathematics; it also plays a key role in helping children make important connections among physical, pictorial, graphic, symbolic, verbal, and mental representations of mathematical ideas. (p. 26)

Beck et al. (2002) promoted research-based strategies for teaching vocabulary to grade school through high school students. These authors suggested that vocabulary instruction should be rich and lively so that students "develop an interest and awareness in words beyond vocabulary school assignments in order to adequately build their vocabulary repertoires" (Beck et al., 2002, p. 13). Beck et al. suggested that explanations of new terms should be student-friendly using everyday language, and activities should engage the students in lively interaction. The intervention employed in the current study provided the students the opportunities to further interact with the words being studied through playing vocabulary games and having a vocabulary journal. A space was dedicated for students to write sentences using the term, drawings, charts, graphs, or graphic organizers. This provided the students an opportunity to put into words what they think they know and how they perceive the words being studied.

Many of the studies laid out in this discussion have highlighted the need for a study of vocabulary to help students learn. The multiple assertions cited in the preceding discussion posit that the study of the vocabulary will help students understand mathematics more, enabling them to perform better in tests. The findings of the study were consistent with all the previous studies and supported that a relationship exists between a directed study of mathematics vocabulary and student level performance on high-stakes standardized mathematics examinations. The understanding of the mathematical terms is crucial in the learning of a student. Steele (1999) explained that the student needs to understand vocabulary from their own perspective and learn it through both oral and written means to have a better understanding of the term. This understanding allows students to better process what the question is asking and can subsequently lead to better test scores.

Previous researchers have posited that it is important that teachers are involved in the vocabulary learning of students. Smith and Angotti (2012) created a planning tool to assist teachers in deciding which words to teach that would help middle level students understand content-area texts and make connections between new concepts and background knowledge. Rubenstein and Thompson (2002) stated, “Because one of the few places students have to ‘talk mathematics’ is in our classrooms, we as teachers must give attention to mathematical language learning” (p. 111). They suggested the teachers include language arts strategies, games, word origins, and children’s books, such as Burns and Silvera’s (2014) The Greedy Triangle and Christaldi and Morehouse’s (2008) Even Steven and Odd Todd, in their teaching.

Further components of the qualitative portion of the study included eight classroom observations of the control teacher and an interview with the control teacher at the completion of the study in December 2016. The questions used for the interview can be found in Appendix D. As discussed in Chapter 4, I found that both the control and experimental teachers had very similar styles of teaching. The most significant difference between procedures in the control and experimental classrooms was the homework policy. In the control classroom, homework may or may not be graded and recorded on a daily basis. Students were required to turn in worksheet pages at the end of each week and were evaluated for completion. Students in my classes turned in homework 3 days a week. Homework was graded by me and returned to students the next day. My students were required to correct homework mistakes and turn them back in for bonus points. Both teachers followed the same curriculum (outlined in Table 2) for the semester when the study took place. This suggests that the same material was covered for both the control and experimental groups, which leads me to believe that the differences in the results of the final quantitative data would be linked to the intervention, given all other conditions were similar.

Results from the current study also showed that ratings provided by the students on their own journal/understanding were not correlated to posttest scores. The ratings provided by me, their teacher, had a moderate positive correlation with posttest scores. This meant that as the rating of the teacher on the journal/understanding of the student increased, the posttest score of the student also increased. This finding is also supportive of the first finding that the study of vocabulary, in this case through an intervention which included a journal, increases posttest scores of students. It was evidenced that the correct learning of terms and concepts of students are associated with increased posttest scores. The contrast between the results of comparing the rating of students on their own journal and posttest scores with the rating of the teacher on the journal of students and posttest scores showed that the intervention implemented by the teacher is important and helpful in ensuring that students get better test scores. These practices are supportive of the many studies that highlighted the importance of teachers in educating students on vocabulary.

Limitations of the Study

There were several limitations encountered in the study. One of the limitations of the study was that the population for the study was from students in two rural schools in central Indiana. A different geographic location could possibly have an effect on the results of the study. The control group teacher was recommended to me by the school counselor from the control school based solely on his opinion that she would be the better of the two pre-algebra teachers for the purposes of the current study at the control group school. I chose this option for choosing the control group teacher because there is no way to find effectiveness data associated with a specific teacher that is reliable and publically available (ISTEP+ scores are not a direct function of the teacher's effectiveness), and subjective ratings on teacher state-mandated reviews are not publically available and, of course, remain subjective. Another limitation of the study was that the study took place in eighth-grade pre-algebra classrooms only. Due to this, the findings of the study may not be applied to students from other levels. Similarly, the sample of the study only included those in pre-algebra class and did not include students considered to be academically advanced. Given the limitations above, the results of the study cannot be generalized. The sample is very specific and only captures a portion of the students. Findings gathered may not hold true for other groups.

Recommendations for Future Research

This study focused on the relationship between a directed study of mathematics vocabulary and results of high-stakes standardized mathematical questions. There are still other aspects of the topic that need further research such as effects of a directed study of mathematics vocabulary on different age groups, ethnicity, identified groups, gender, and other categories of interest. These aspects can be taken into consideration by future researchers who plan to explore further the factors that can affect high-stakes standardized mathematical test scores.

The current study focused only on eighth-grade students. An extension of this study can be done to include other grade levels to investigate if the same results are observable. Future researchers may choose to focus on other grade levels to explore particularities of practice at different levels and whether the same results can be replicated.

Future researchers may also include other factors such as gender, ethnicity, identified students, and/or socioeconomic levels as part of the demographic data to analyze if there is any difference in the results. In my study I focused on both girls and boys, but did not provide any further details on these students. Genders could be separated to compare results of male versus female students. Although literature does not address any relationship between these variables and posttest scores, it would be worth including to identify and confirm if factors such as those listed above indeed have no impact.

As stated in the results section of this chapter, the journal/understanding scores given by students in their vocabulary journals were not significantly associated with pretest scores, $r = -0.04$, $p = 0.756$, but posttest scores were significantly associated with journal/understanding scores assigned by the teacher, $r = 0.38$, $p = 0.005$. Higher posttest scores were associated with higher journal/understanding scores, with a moderately positive correlation. Another area for future research would question why student's ratings of their understanding of each term in their own journal did not correlate with their posttest scores. However, my rating of their journal entries did correlate.

An additional study that could be done is to compare the results of this study to a different geographic area to identify how location affects results of posttest scores. This would allow other researchers to identify how consistent results are across the country and could possibly help to make generalization more applicable.

Implications for Practice

The results of the study may have implications for different stakeholders including legislators, school officials, educators, and students themselves. The findings of the study highlighted the importance of this intervention and how it affected the test scores of students. With such results, the results of this study contribute to the body of literature on mathematical vocabulary and high-stakes tests.

One of the important implications is the possible effects of this at an organizational level. Many organizations could draw from the results of this study to address the current concerns regarding the high-stakes test scores of students and their readiness for postsecondary education or for work without the need for remediation. When Indiana adopted new academic standards for Language Arts and Mathematics, there was the hope that by the time students graduated from high school, they would be ready and well-equipped should they decide to take further studies or join the workforce. With the findings of this study, educators can assess the current programs and approaches they have in addressing high-stakes test results. As evidenced by the intervention done in this study, having a directed study of mathematical vocabulary impacts test scores positively.

School professionals such as teachers, administrators, and curriculum directors can assess and review the intervention done in this study and explore replicating or incorporating the approach in their curriculum. With the increase in test scores due to a directed study of mathematical vocabulary, school officials may consider this approach to increase the learning of students and as a result, increase their test scores on high-stakes examinations. Having the school supporting in this kind of change in approach will be crucial as they are responsible for preparing and mentoring students for these high-stakes examinations.

Teachers can also draw from the results of these studies. This provides them a view of how intervention is done and how it helps students have a better understanding of mathematics. Having a vocabulary journal as demonstrated in Figure 14 gives structure for the study of each term and provides a means for adding to the students' personal knowledge of a term. The vocabulary journal also provides a written record that students can refine as more is learned about the term and a resource students can refer to as needed when problem solving and for repeated review of each term. It is important that teachers understand and know how to provide this approach should officials decide to adopt and incorporate this approach in the curriculum to increase test scores of students. The success of this approach, as discussed in several of the studies provided in the literature, is also dependent on the teachers as they are the ones administering this methodology. As previously noted, some students complained about being asked to write in their vocabulary journals and would rush through their journal work as quickly as they could. When this happened, I needed to intervene and encourage students to complete their journal work, informing them this work required a higher level of thinking about the term that would pay off in understanding.

Having taught middle school mathematics in the public school classroom for 44 years, I often contemplated a directed study of mathematics vocabulary. However, I felt that it would take too much time away from preparing my students for the required standardized tests. By having the vocabulary journal as a guide helped in following the planned intervention in this study. I found that studying mathematics vocabulary enhanced the teaching of the standards, helping my students express themselves using OML and retaining the meaning of the vocabulary terms.

Lastly, the students can also take away some information from this study. It is important to have students understand the need for such an approach should it be used. The findings can show students that learning vocabulary helps them perform better in high-stakes examinations.

Conclusion

High-stakes examination scores for mathematics have been a concern as they are used as the basis for determining if a student is ready to attend post-secondary education or build a career. Researchers in the body of literature have highlighted the importance of vocabulary in understanding mathematics. The purpose of this study was to determine whether there is a significant effect from a directed study of mathematics vocabulary on high-stakes standardized mathematical questions for eighth-grade students enrolled in pre-algebra in a rural school in southern Indiana. Results showed that students who received intervention through a directed study of mathematical vocabulary had significantly higher posttest scores compared to the group who did not receive treatment, which rejects the null hypothesis. Additional analyses also showed that the rating given by the teacher on the journal/understanding of the student is positively correlated with the posttest scores; however, the rating of students on their own journal/understanding did not have any correlation with the posttest scores. Future research is suggested to include other factors such as gender, ethnicity, identified students, and/or socioeconomic level as part of the demographic data to analyze if there is any difference in the results. Geographic data may also be used to compare results after using the Intervention in different locations. Organizational educators, curriculum directors, teachers, administrators, and other school professionals can draw from the results of this study to aid them in addressing current concerns regarding the high-stakes test scores of students and their readiness for postsecondary education or for work without the need for remediation.

"Because one of the few places students have to 'talk mathematics' is in our classrooms, we as teacher must give attention to mathematical language learning" (Rubenstein & Thompson, 2002, p. 111). As proficiency in mathematics continues to become more reliant upon a child's ability to understand and use mathematical vocabulary, educators need to search for ways that students can develop a deeper understanding of the mathematical vocabulary used on high-stakes tests, in the classroom, and in the real world.

REFERENCES

Acuity Assessment System. (2016). Retrieved from https://www.mheonline.com/acuity/

Adams, T. L. (2003). Reading mathematics: More than words can say. *The Reading Teacher, 56*(8), 786-795.

Adams, T., Thangata, F., & King, C. (2005). "Weigh" to go. *Mathematics Teaching in the Middle School, 10*(9), 444-448.

Allen, J. (1999). *Tools for teaching academic vocabulary.* Portland, ME: Stenhouse.

Advanced Learning Technologies in Education Collaborative at University of Kansas. (n.d.). Rubistar: Create rubrics for your project-based learning activities. Retrieved from http://rubistar.4teachers.org/index.php

Baumann, J., & Kame'enui, E. (2012). *Vocabulary instruction* (2nd ed.). New York, NY: Guilford.

Beck, I. L., McKeown, M. G., & Kucan, L. (2002). *Bringing words to life: Robust vocabulary instruction.* New York, NY: Guilford.

Blachowicz, C. L., & Fisher, P. (2002). *Teaching vocabulary in all classrooms.* Upper Saddle River, NJ: Merrill/Prentice Hall.

Blake, B., & Pope, T. (2008). Developmental psychology: Incorporating Piaget’s and Vygotsky’s theories in classrooms. *Journal of Cross-Disciplinary Perspectives in Education*, 1(1), 59-67. Retrieved from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C15&q=Piaget%2C+J.+%282008%29.+Developmental+psychology%3A+Incorporating+Piaget%E2%80%99s+and+Vygotsky%E2%80%99s+theories+in+classrooms.&btnG=

Borim, M. P. (2000). Curriculum and evaluation standards for school mathematics. Reston, VA: NCTM.

Brenneman, R. (2014, November 10). Math-exam performance tasks ratchet up expectations, anxiety. *Education Week.* Retrieved from http://www.edweek.org/ew/articles/2014/11/12/12cc-performance.h34.html

Brooks, J., & Brooks, M. (1999). *In search of understanding: The case for constructivist classrooms.* Alexandria, VA: Association for Supervision and Curriculum Development.

Burger, E., Dixon, T., Kanold, J., Larson, M., Leinwand, S., & Sandoval-Martinez, M. (2014). *Go Math Middle School Grade 8*. Orlando, FL: Houghton Mifflin Harcourt.

Burns, M. (2006). Marilyn Burns on the language of math. *Instructor*, *115*(7), 41-43.

Burns, M., & Silveria, G. (2014). *The greedy triangle*. United States: Paw Prints.

Capraro, R. M., & Capraro, M. M. (2006). *Are you really going to read us a story? Learning geometry through children's mathematics literature.* New York, NY: Routledge.

Colburn, A. (2000). Constructivism: Science education's "grand unifying theory." *The Clearing House, 74*(1), 10-12.

Corson, D. (1997). The learning and use of academic English words. *Language Learning, 47*(4), 671-718.

Cristaldi, K., & Morehouse, H. B. (2008). Even Steven and odd Todd. New York, NY: Scholastic.

Daniels, H. (2001). *Vygotsky and pedagogy*. NewYork, NY: Routledge Falmer.

Dewey, J. (2009). *Democracy and education: An introduction to the philosophy of education*. Waiheke Island, New Zealand: Floating Press.(original work published 1916)

Dimitrov, D. M., & Rumrill, P. D. (2003). Pretest-posttest designs and measurement of change. *Work, 20*(2), 159-165.

Education Alliance of Brown University. (n.d.). High-Stakes Testing. Retrieved October 29, 2017, from https://www.brown.edu/academics/education-alliance/teaching-diverse-learners/assessment/high-stakes-testing-0

Ely, E., Kennedy, M. J., Pullen, P. C., Williams, M. C., & Hirsch, S. E. (2014). Improving instruction of future teachers: A multimedia approach that supports implementation of evidence-based vocabulary practices. *Teaching and Teacher Education, 44*(1), 35-43.

Fisher, P., & Blachowicz, C. (2013). A few words about math and science. *Educational Leadership*, *71*(3), 46-51.

Graves, M. F. (2006). *The vocabulary book: Learning and instruction.* New York, NY: Teacher's College.

Harmon, J. M., Hedrick, W. B., & Wood, K. D. (2005). Research on vocabulary instruction in the content areas: Implications for struggling readers. *Reading & Writing Quarterly, 21*, 261-280.

Hea-Jin, L., & Herner-Patnode, L. M. (2007). Teaching mathematics vocabulary to diverse groups. *Intervention in School & Clinic, 43*(2)**,** 121-126.

Heitin, L. (2014, November 10). *Common Core redoes the math. Education Week.* Retrieved from http://www.edweek.org/ew/articles/2014/11/12/12cc-overview.h34.html

Herbel-Eisenmann, B. A. (2002). Using student contributions and multiple representations to develop mathematical language. *Mathematics Teaching in the Middle School, 8*(2), 100-105.

Heubert, J. P. (2000). High-stakes testing: Opportunities and risks for students of color, English-language learners, and students with disabilities. Wakefield, MA: National Center on Accessing the General Curriculum. Center for Applied Special Technology.

Hung, D. W. (2002). Metaphorical ideas as mediating artifacts for the social construction of knowledge: Implications from the writings of Dewey and Vygotsky. *International Journal of Instructional Media, 2*(1), 197.

Huson, J. A. (n.d.). The advantages of traditional schools. Retrieved September 15, 2017, from http://education.seattlepi.com/advantages-traditional-schools-2140.html

Indiana Department of Education. (2011). Indiana Academic Standards. Retrieved October 29, 2017, from https://www.doe.in.gov/standards/mathematics

Indiana Department of Education. (2015a). Indiana Academic Standards. Retrieved from http://www.doe.in.gov/standards

Indiana Department of Education. (2015b). *ISTEP+ infocenter*. Retrieved from http://www.doe.in.gov/istep/

Indiana Department of Education. (2017a). Compass. Retrieved from http://compass.doe.in.gov/dashboard/overview.aspx?type=school&id=6597

Indiana Department of Education. (2017b). Find school and corporation data reports. Retrieved September 15, 2017, from https://www.doe.in.gov/accountability/find-school-and-corporation-data-reports.

Indiana Department of Education. (2017c). Indiana Academic Standards. Retrieved from http://www.doe.in.gov/standards

Jonassen, D. H. (1994). Thinking technology: Toward a constructivist design model. *Educational Technology, 34*(4), 34-37.

Jonassen, D.H. (2003). *Learning to solve problems with technology: A constructivist perspective* (2nd ed.). Upper Saddle River, NJ: Merrill.

Jones, B. R., Hopper, P. F., & Franz, D. P. (2008). Mathematics: A second language. *Mathematics Teacher, 102*(4), 307-312.

Kenney, J. M., Hancewicz, E., Heuer, L., Metsisto, D., & Tuttle, C. L. (2006). *Literacy strategies for improving mathematics instruction.* Alexandria, VA: Association for Supervision and Curriculum Development.

Lappan, G. (1991). Professional standards for teaching mathematics. Reston (Virginia): NCTM.

Layton, L. (2013, January 16). *Majority of U.S. public school students are in poverty*. Retrieved from https://www.washingtonpost.com/local/education/majority-of-us-public-school-students-are-in-poverty/2015/01/15/df7171d0-9ce9-11e4-a7ee-526210d665b4_story.html

Lindquist, M. (1996). Mathematics as a language. In P. C. Elliot & M. J. Kenney (Eds.), *1996 yearbook: Communication in mathematics, k-12 and beyond,* (p. 2), Reston, VA: National Council of Teachers of Mathematics.

Marzano, R. J., & Pickering, D. J. (2005). *Building academic vocabulary: Teacher's manual,* Alexandria, VA: Association for Supervision and Curriculum Development.

MATH-PLAY. (n.d.). Retrieved from http://www.math-play.com/rational-and-irrational-numbers-game/rational-and-irrational-numbers-game.html

McGraw Hill Education. (n.d.). Study confirms positive effects of Acuity interim assessments for Reading and Mathematics. Retrieved September 12, 2017, from http://www.mheducation.com/blog/product-updates/study-confirms-positive-effects-acuity-interim-assessments-reading-and-mathematics.html

Miller, D. (1993). Making the connection with language. *The Arithmetic Teacher, 40*(6), 311-316. Retrieved from http://www.jstor.org/stable/41195589

Miura, I. T. (2001). The influence of language on mathematical representations. In A. A. Cuoco & F. R. Curcio (Eds.), *The roles of representation in school mathematics: 2001 yearbook* (pp. 53-62), Reston, VA: National Council of Teachers of Mathematics.

Murray, M. (2004). *Teaching mathematics vocabulary in context: Windows, doors, and secret passageways.* Toronto, Ontario: Pearson Education Canada.

National Council of Teachers of Mathematics. (2000). Curriculum and evaluation standards for school mathematics. Reston, VA: Author.

Nguyen, T. T. H., & Khuat, T. T. N. (2003). The effectiveness of learning vocabulary through games. *Asian EFL Journal, 5*(4)

Owen, S. V., & Froman, R. D. (1998). Focus on qualitative methods uses and abuses of the analysis of covariance. *Research in Nursing and Health, 21*(6), 557-562.

Peters, C. W. (1975). A comparison between the Frayer model of concept attainment and the textbook approach to concept attainment. *Reading Research Quarterly, 10*, 252–254.

Piaget, J. (1970). Piaget's theory. In P. Mussen (Ed.), *Carmichael's manual of child psychology* (Vol. 1, 3rd ed., pp. 703-732). New York, NY: Wiley.

Piaget, J., & Inhelder, B. (1969). *The psychology of the child.* New York, NY: Basic Books.

Pierce, M. E., & Fontaine, L. M. (2009). Designing vocabulary instruction in mathematics. *The Reading Teacher, 63*(3), 239-243. doi:10.1598/rt.63.3.7

Renne, C. G. (2004). Is a rectangle a square? Developing mathematical vocabulary and conceptual understanding. *Teaching Children Mathematics, 10*(5), 258-263.

Riccomini, P. J., Smith, G. W., Hughes, E. M., & Fries, K. M. (2015). The language of mathematics: The importance of teaching and learning mathematical vocabulary. *Reading & Writing Quarterly, 31*(3), 235-252.

Rubenstein, R. N. (2000). Word origins: Building communications connections. *Mathematics Teaching in the Middle School, 5*(8)**,** 493-498.

Rubenstein, R. N. (2007). Focused strategies for middle-grades mathematics vocabulary development. *Mathematics Teaching in the Middle School, 13*(4)**,** 200-207.

Rubenstein, R., & Thompson, D. (2002). Understanding and supporting children's mathematical vocabulary development. *Teaching Children Mathematics, 9*(2), 107-112. Retrieved from http://www.jstor.org/stable/41197988

Schell, V. J. (1982). Learning partners: Reading and mathematics. *The Reading Teacher,* 35(5)**,** 544-548.

Shorrocks-Taylor, D., & Hargreaves, M. (1999). Making it clear: A review of language issues in testing with special reference to the national. *Educational Research, 41*(2), 123.

Smith, A. T., & Angotti, R. L. (2012). Why are there so many words in math?" Planning for content-area vocabulary instruction. *Voices from the Middl*e, *20*(1), 43-51.

Steele, D. (1999). Learning mathematical language in the zone of proximal development. *Teaching Children Mathematics, 6*(1), 38-42.

Thompson, D. R., & Rubenstein, R. N. (2000). Learning mathematics vocabulary: Potential pitfalls and instructional strategies. *Mathematics Teacher, 93*(7), 568.

Usiskin, Z. (1996). Mathematics as a language. In P. C. Elliot & M. J. Kenney (Eds.), *1996 yearbook: Communication in mathematics, k-12 and beyond,* (pp. 231-243), Reston, VA: National Council of Teachers of Mathematics.

Vygotsky, L. S. (1962). *Thought and language*. Cambridge, MA: Massachusetts Institute of Technology.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Wilson, B. G. (2012). Constructivism in practical and historical context. *Trends and Issues in Instructional Design and Technology, 3,* 45-52.

Xuan, J., & Perkins, K. (2013). A conceptual paper on the application of the picture word inductive model using Bruner's constructivist view of learning and the cognitive load theory. *Interdisciplinary Journal of Teaching & Learning, 3*(1), 8-17.

APPENDIX A: LETTER OF PERMISSION FROM ASSOCIATION FOR SUPERVISION AND CURRICULUM DEVELOPMENT

This appendix consists of a letter from the Association for Supervision and Curriculum Development (ASCD) giving permission to use material from Marzano and Pickering's (2005) book Building Academic Vocabulary: Teacher's Manual.

RE: request permission to use copyright material in dissertation (Thread:1347545)

Permissions <permissions@ascd.org>

Mon 7/13/2015 2:03 PM

Inbox

To: Adel Waite <awaite@sycamores.indstate.edu>;

Dear Adel:

In response to your request below, please consider this permission to use the excerpt(s) from the referenced publication for your personal research purposes. Should you include excerpts or cite content in a paper or some other report form, please credit the source accordingly. If your research results in use of our content in a product or publication for commercial release, please contact me again to secure further rights to do so.
Thank you for your interest in ASCD and good luck with your dissertation.

Sincerely yours,

KATY WOGEC • Sr. Paralegal
1703 N. Beauregard Street • Alexandria, VA 22311-1714
P 703-575-5749 · F 703-575-3926 · **www.ascd.org** · www.wholechildeducation.org

Description: Description: cid:image001.png@01CC3269.603B0FA0

Join us: D D D

From: Adel Waite [mailto:awaite@sycamores.indstate.edu]
Sent: Monday, July 13, 2015 11:58 AM
To: permission@ascd.org
Subject: request permission to use copyright material in dissertation (Thread:1347545)

Katy,

I spoke with you on the phone about acquiring written permission to use some of Marzono's materials in my dissertation entitled *EFFECT OF DIRECTED STUDY OF MATHEMATICS VOCABULARY ON STANDARDIZED MATHEMATICS ASSESSMENT SCORES.*

I am asking permission to use the following as part of my directed study to use excerpts, activities, and games from:

Marzano, R. J., & Pickering, D. J. (2005) *Building academic vocabulary: Teacher's manual,* Alexandria, VA: Association for Supervision and Curriculum Development.

- A Six-Step Process for Teaching new Terms - begins on page 14.
- Ch 4 - Review Activities and Games - begins on page 38. I would like to use some of the figures and games.

Of course I will cite all materials using APA formatting.

Thank you for your consideration.

Sincerely,
Adel Marlane Waite
Doctoral Candidate, Indiana State University
Terre Haute, IN

My contact information:
Marlane Waite
8015 S Meridian Rd.
Clay City, IN 47841
Cell: 812.201.6503

APPENDIX B: PERMSISSION TO USE GO MATH MATERIALS

This appendix consists of a letter from Houghton Mifflin Harcourt granting permission to use select pages Vocabulary Preview, page 2; Real Numbers diagram, page 15; Vocabulary Preview, page 66; Reading Start-Up, page 68 and Reading Start-Up, page 124, in my dissertation titled “Effect of Directed Study of Mathematics Vocabulary on Standardized Mathematics Assessment Questions” from our *GO MATH!,* Student Edition, Grade 8, for submission to Indiana State University.

Indiana State University Follow-through on permission for Waite's dissertation

PS

Permissions, School <SchoolPermission@hmhco.com>

Reply all|

Today, 8:10 PM

Adel Waite

Dear Ms. Waite:

Thank you for your email inquiry requesting permission to include select pages Vocabulary Preview, page 2; Real Numbers diagram, page 15; Vocabulary Preview, page 66; Reading Start-Up, page 68 and Reading Start-Up, page 124, in your dissertation titled “Effect of Directed Study of Mathematics Vocabulary on Standardized Mathematics Assessment Questions” from our *GO MATH!,* Student Edition, Grade 8, for submission to Indiana State University.

We are pleased to grant your request on a one-time, nonexclusive, and nontransferable basis as stated, provided that you agree not to portray our copyrighted material in a negative manner, and that no deletions from, additions to, or changes in the material will be made without prior written approval of Houghton Mifflin Harcourt Publishing Company. This license only applies to use of our copyrighted material specified above as examples in your research paper, and does not authorize mechanical or electronic reproduction in any form. Permission granted herein is limited to material owned by Houghton Mifflin Harcourt Publishing Company.

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Thank you for your interest in our publications.

Sincerely,

Mary Rodriguez
Senior IP Analyst Outbound Licensing
Product Planning, Development, and Marketing
Shared Services

Houghton Mifflin Harcourt
9400 Southpark Center Loop
Orlando, FL 32819
Phone: 407.345.3797
Fax: 407.345.2418
hmhco.com

From: Adel Waite [mailto:awaite@sycamores.indstate.edu]
Sent: Monday, October 09, 2017 3:24 PM
To: Permissions, School
Subject: Indiana State University Follow-through on permission for Waite's dissertation

This message originated from outside your organization

Dear Ms. Rodriguez,

I will defend my dissertation tomorrow, October 10, 2017, and need your final answer as to whether or not I have permission to use the following in my written dissertation as explained in the previous emails with you:

- Vocabulary Preview page 2
- Real Numbers diagram page 15
- Vocabulary Preview page 66
- Reading Start-Up page 68
- Reading Start-Up page 124

I left you a voice mail but then thought you might be out for Columbus day. When you can get to this, I would really appreciate your reply.

Thank you so much!

Adel Waite

From: Adel Waite
Sent: Thursday, August 17, 2017 12:32 PM
To: Permissions, School
Subject: Re: Indiana State University Request Permission for use in dissertation

Dear Ms. Rodriguez,

I have answered your questions below.

What is the ISBN of our content on which your activity is based? 978-0-544-05678-7

How will our content be used?

The excerpt where the content is used is attached.

Will you only reference our content in the appendix, or will you be including the actual content in your dissertation and appendix?

I will reference the content in my dissertation as shown in the attachment. I do not have an index in my document.

Will this be in print format only?

My dissertation is for Indiana State University and will be submitted online to my committee and others in the department who must approve it. I must also submit to them a copy in print at my dissertation defense.

Thank you again for your consideration.

Adel Marlane Waite

From: Permissions, School <SchoolPermission@hmhco.com>
Sent: Thursday, August 17, 2017 11:37:03 AM
To: Adel Waite
Subject: RE: Indiana State University Request Permission for use in dissertation

Dear Ms. Waite,

Thank you for your email inquiry below regarding assessment questions for use in your dissertation. In order to process your request I will need some additional information.

What is the ISBN of our content on which your activity is based?

How will our content be used?

Will you only reference our content in the appendix, or will you be including the actual content in your dissertation and appendix?

Will this be in print format only?

Thank you for your assistance.

Regards,

Mary Rodriguez

Senior IP Analyst Outbound Licensing

Product Planning, Development, and Marketing

Shared Services

Houghton Mifflin Harcourt

9400 Southpark Center Loop

Orlando, FL 32819

Phone: 407.345.3797

Fax: 407.345.2418

hmhco.com

From: Adel Waite [mailto:awaite@sycamores.indstate.edu]
Sent: Tuesday, August 15, 2017 2:21 PM
To: Permissions, School
Subject: Request Permission for use in dissertation

This message originated from outside your organization

I wish to request the use of the following vocabulary activities in my dissertation entitled: EFFECT OF DIRECTED STUDY OF MATHEMATICS VOCABULARY ON STANDARDIZED MATHEMATICS ASSESSMENT QUESTIONS.

I used these activities in my classroom as part of the treatment for a directed study of vocabulary and with your permission would like to print them in my dissertation as some of the activities that I used with my students during our directed study of math vocabulary:

- Vocabulary Preview page 2
- Real Numbers diagram page 15
- Vocabulary Preview page 66
- Reading Start-Up page 68
- Reading Start-Up page 124

I looked online and began filling out a request but the form did not meet what I was asking for.

Thank you for your consideration.

Sincerely,

Adel Marlane Waite

Doctoral Candidate

Indiana State University, Terre Haute, IN

APPENDIX C: PARENTAL CONSENT AND STUDENT ASSENT FORMS

This appendix consists of student assent and parental permission forms approved by the Indiana State University Institutional Research Board for both the experimental and control schools in this study.

EXPERIMENTAL GROUP ASSENT TO PARTICIPATE IN RESEARCH

Will studying vocabulary in math help me score better on math test questions?

1. My name is [Identity Redacted] and I am the research assistant for Mrs. Marlane Waite, a doctoral candidate from Indiana State University.
2. We are asking you to take part in a research study because we are trying to learn more about students your age taking math tests like ISTEP+. We want to know if studying vocabulary a certain way can help students your age do better on these types of tests.
3. If you agree to be in this study, we will use your scores from a pretest and a posttest that is designed to see if you know certain vocabulary words. Both tests will be multiple-choice and matching and will be given to you in your math class by your math teacher.
4. If you agree to let us use your scores, they will be evaluated without your name on it and will be reported as part of a group with all the other scores.
5. If your parents/guardians and you agree to allow your scores to be used in the study, your name will be placed in a drawing for a $10 gift card from Walmart. There will be 50 students from this school and 50 students from a nearby school participating in this study. ALL 100 names of the participants will be placed in the drawing and ten $10 gift cards will be given away. This means your chances of winning are 1 in 10. The drawing will be conducted by me, Mrs. Waite's research assistant, in January 2017. If you win a gift card, I will personally hand the card to you at school. You are still eligible to be included in the drawing even if you withdraw from the study, including if you move from the district during the study. Please ensure that if you move from the district that your parent or guardian has given the school office a forwarding address so that the card may be mailed to you should you win. The names of the winners cannot be announced, but there will be an announcement in your math class that the gift cards have been awarded. This way, you won't have to wonder if you won a card or not.
6. There are no risks to you if you decide to let us use your scores. Your name will not be connected to your score or reported to anyone.
7. Although there are no benefits to you at this time, this study will help educators make decisions in the future about how they should teach mathematics vocabulary to their students.
8. If your parents have given their permission for you to take part in this study, you also have to agree in order for your scores to be part of this study. If your parents did not give permission, then your scores will not be a part of this study.
9. If you don't want to be in this study, you don't have to participate. Remember, being in this study is up to you and no one will be upset if you don't want to participate or even if you change your mind later and want to stop.
10. At this time, you can ask any questions that you have about the study. If you have a question later that you didn't think of now or if you later want to change your mind about participating, you can call me, [Identity Redacted], at [Phone Number Redacted], talk or email me at [Email Redacted].

11. Please choose below if you “Will Participate” or “Will Not Participate,” sign your name, fold it, place it in the envelope I gave you, and then hand it in to me.

__________ I will participate. __________ I will NOT participate.

____ ___________

Signature of Student Date

____

Printed Name of Student
Printed Name of Student

PARENT PERMISSION

When the 2016-17 school year begins, your 8th grade mathematics student will be asked to take a pretest in his or her mathematics class assessing his or her knowledge of mathematics vocabulary. **At the conclusion of the fall semester**, he or she will take a posttest to assess student vocabulary progress.

I am asking your permission to use your child's scores in a research project that will investigate if a directed study of mathematics vocabulary improves student performance on standardized multiple choice questions. If you and your child agree to allow his or her scores to be used in this study, your child's name will be placed in a drawing for a $10 gift card from Walmart. There will be 50 students from your child's school and 50 students from a nearby school participating in this study. ALL 100 names of the participants will be placed in the drawing and ten $10 gift cards will be given away. This means your chances of winning are 1 in 10. The drawing will be conducted by Mrs. Waite's research assistant, in January 2017. If you win a gift card, the research assistant will personally hand the card to your child at school. Your child is still eligible to be included in the drawing even if he or she withdraws from the study, including if he or she moves from the district during the study. The names of the winners cannot be announced, but there will be an announcement in your child's math class that the gift cards have been awarded. This way, you and your child won't have to wonder if he or she won a card or not. Please ensure that if your child moves from the district that you give the school office a forwarding address so that the card may be mailed to your child should he or she win.

All scores will be analyzed as part of a group and **at no time will your student's scores be individually reported**. The details of the study may be found attached to this paper.

Please indicate if you will allow your child's scores to be used in this project by checking one of the statements below and signing your name. **Please fold and put this pink paper in the attached envelope, seal it, and hand it in with the rest of your registration materials. You are encouraged to keep the attached white paper for your records.**

_____ I grant permission for my child to participate in this vocabulary study.

_____ I do not grant permission for my child to participate in this vocabulary study.

Signature of Parent/Guardian	Printed Parent/Guardian Name
Printed Name of Child	Date

Only the first page of this document (the pink page) needs to be folded and placed in the envelope provided and turned in to the office. This part of the document is to be taken home by you for future reference.

Dear Parent or Guardian:

I am a doctoral candidate in the Department of Teaching and Learning at Indiana State University. I am conducting a research project that will investigate if a directed study of mathematics vocabulary improves student performance on standardized multiple choice questions. I request permission for your child to participate by allowing me to use your child's test scores from a pretest and a posttest given which will be given in your child's mathematics class.

The pretest and posttest will assess his or her understanding of selected math vocabulary. That is all that will be required of your child. These tests will not affect your child's grade in any way. The project will be explained in terms that your child can understand, and your child will participate only if he or she is willing to do so. Only I and my research assistant will have access to information from your child. At the conclusion of the study, the children's responses will be reported as group results only.

Participation in this study is voluntary. Your decision whether or not to allow your child to participate will not affect the services normally provided to your child by [Identity Redacted] Middle School and his or her mathematics teacher. Even if you give your permission for your child to take part in the study, your child is free to refuse. If you and your child agree to allow his or her scores to be used in this study, your child's name will be placed in a drawing for a $10 gift card from Walmart. There will be 50 students from your child's school and 50 students from a nearby school participating in this study. ALL 100 names of the participants will be placed in the drawing and ten $10 gift cards will be given away. This means your chances of winning are 1 in 10. The drawing will be conducted by Mrs. Waite's research assistant, in January 2017. If you win a gift card, the research assistant will personally hand the card to your child at school. Your child is still eligible to be included in the drawing even if he or she withdraws from the study, including if he or she moves from the district during the study. The names of the winners cannot be announced, but there will be an announcement in your child's math class that the gift cards have been awarded. This way, you and your child won't have to wonder if he or she won a card or not. Please ensure that if your child moves from the district that you give the school office a forwarding address so that the card may be mailed to your child should he or she win.

Even if your child agrees to take part, he or she is free to stop at any time. You and your child are not waiving any legal claims, rights, or remedies because of your child's participation in this research study.

If you have any questions, please call my Research Assistant at [Identity Redacted] and ask for Mrs. [Identity Redacted] or email her at [Email Redacted]. Please keep this letter for your information but fill out and return the form on the attached page.

If you have any questions about your rights as a parent or your child as a research subject, please contact the Indiana State University Institutional Review Board (IRB). Contact information is given below. The IRB is an independent committee of members of the University community and members of the community not connected with ISU. The IRB has reviewed and approved this study.

Sincerely,

Marlane Waite

[Identity Redacted] Middle School Math Teacher
Indiana State University Doctoral Candidate

PLEASE SAVE THIS DOCUMENT FOR FUTURE REFERENCE

If you have agreed to allow the two scores from your child's pretest and posttest of mathematics vocabulary to be used in the study, and **later change your mind**, you may do one of the following:

- Mail this form to [Identity Redacted] at [Address Redacted]
- Call 812-829-2249 and ask for Mrs. [Identity Redacted].
- Email [Identity Redacted] at [Email Redacted]

_____ I no longer want my child's scores used from the pretest and posttest for this study of mathematics vocabulary. Please remove his or her data from the study.

Parent signature ____ Date _____________

Print Student's name ____

Indiana State University Institutional Review Board, Office of Sponsored Programs
Terre Haute, IN 47809
Phone: (812) 237-8217
E-mail: irb@indstate.edu

CONTROL GROUP ASSENT TO PARTICIPATE IN RESEARCH

Will studying vocabulary in math help me score better on math test questions?

1. My name is [Identity Redacted] and I am the research assistant for Mrs. Marlane Waite, a doctoral candidate from Indiana State University.
2. We are asking you to take part in a research study because we are trying to learn more about students your age taking math tests like ISTEP+. We want to know if studying vocabulary a certain way can help students your age do better on these types of tests.
3. If you agree to be in this study, we will use your scores from a pretest and a posttest that is designed to see if you know certain vocabulary words. Both tests will be multiple-choice and matching and will be given to you in your math class by your math teacher.
4. If you agree to let us use your scores, they will be evaluated without your name on it and will be reported as part of a group with all the other scores.
5. If your parents/guardians and you agree to allow your scores to be used in the study, your name will be placed in a drawing for a $10 gift card from Walmart. There will be 50 students from this school and 50 students from a nearby school participating in this study. ALL 100 names of the participants will be placed in the drawing and ten $10 gift cards will be given away. This means your chances of winning are 1 in 10. The drawing will be conducted by me, Mrs. Waite's research assistant, in January 2017. If you win a gift card, I will personally hand the card to you at school. You are still eligible to be included in the drawing even if you withdraw from the study, including if you move from the district during the study. Please ensure that if you move from the district that your parent or guardian has given the school office a forwarding address so that the card may be mailed to you should you win. The names of the winners cannot be announced, but there will be an announcement in your math class that the gift cards have been awarded. This way, you won't have to wonder if you won a card or not.

1. There are no risks to you if you decide to let us use your scores. Your name will not be connected to your score or reported to anyone.
2. Although there are no benefits to you at this time, this study will help educators make decisions in the future about how they should teach mathematics vocabulary to their students.
3. If your parents have given their permission for you to take part in this study, you also have to agree in order for your scores to be part of this study. If your parents did not give permission, then your scores will not be a part of this study.
4. If you don't want to be in this study, you don't have to participate. Remember, being in this study is up to you and no one will be upset if you don't want to participate or even if you change your mind later and want to stop.
5. At this time, you can ask any questions that you have about the study. If you have a question later that you didn't think of now or if you later want to change your mind about participating, you can call me, [Identity Redacted], at [Phone Number Redacted] or email me at [Email Redacted].

6. Please choose below if you "Will Participate" or "Will Not Participate," sign your name, fold it, place it in the envelope I gave you, and then hand it in to me.

__________ I will participate. __________ I will NOT participate.

_____________________________________ ___________

Signature of Student Date

____

Printed Name of Student

PARENT PERMISSION

When the 2016-17 school year begins, your 8th grade mathematics student will be asked to take a pretest in his or her mathematics class assessing his or her knowledge of mathematics vocabulary. **At the conclusion of the fall semester**, he or she will take a posttest to assess student vocabulary progress.

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All scores will be analyzed as part of a group and **at no time will your student's scores be individually reported**. The details of the study may be found attached to this paper.

Please indicate if you will allow your child's scores to be used in this project by checking one of the statements below and signing your name. **Please fold and put this pink paper in the attached envelope, seal it, and hand it in with the rest of your registration materials. You are encouraged to keep the attached white paper for your records.**

_____ I grant permission for my child to participate in this vocabulary study.

_____ I do not grant permission for my child to participate in this vocabulary study.

______________________________	______________________________
Signature of Parent/Guardian	Printed Parent/Guardian Name
______________________________	______________________________
Printed Name of Child	Date

Only the first page of this document (the pink page) needs to be folded and placed in the envelope provided and turned in by your child to his or her first period teacher who will then turn it in to the school office. The white paper is to be kept at home by you for future reference.

Marlane Waite
[Identity Redacted] Middle School

Dear Parent or Guardian:

I am a doctoral candidate in the Department of Teaching and Learning at Indiana State University. I am conducting a research project that will investigate if a directed study of mathematics vocabulary improves student performance on standardized multiple choice questions. I request permission for your child to participate by allowing me to use your child's test scores from a pretest and a posttest given which will be given in your child's mathematics class.

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Participation in this study is voluntary. Your decision whether or not to allow your child to participate will not affect the services normally provided to your child by [Identity Redacted] Middle School and his or her mathematics teacher. Even if you give your permission for your child to take part in the study, your child is free to refuse. If you and your child agree to allow his or her scores to be used in this study, your child's name will be placed in a drawing for a $10 gift card from Walmart. There will be 50 students from your child's school and 50 students from a nearby school participating in this study. ALL 100 names of the participants will be placed in the drawing and ten $10 gift cards will be given away. This means your child's chances of winning are 1 in 10. The drawing will be conducted by Mrs. Waite's research assistant, in January 2017. If your child wins a gift card, the research assistant will personally hand the card to your child at school. Your child is still eligible to be included in the drawing even if he or she withdraws from the study, including if he or she moves from the district during the study. The names of the winners cannot be announced, but there will be an announcement in your child's math class that the gift cards have been awarded. This way, you won't have to wonder if you won a card or not. Please ensure that if your child moves from the district that you give the school office a forwarding address so that the card may be mailed to your child should he or she win.

Even if your child agrees to take part, he or she is free to stop at any time. You and your child are not waiving any legal claims, rights, or remedies because of your child's participation in this research study.

If you have any questions, please call my Research Assistant at [Phone Number Redacted] and ask for [Identity Redacted] or email her at [Email Redacted]. Please keep this letter for your information but fill out and return the form on the attached page.

If you have any questions about your rights as a parent or your child as a research subject, please contact the Indiana State University Institutional Review Board (IRB). Contact information is given below. The IRB is an independent committee of members of the University community and members of the community not connected with ISU. The IRB has reviewed and approved this study.

Sincerely,

Marlane Waite
[Identity Redacted] Middle School, Teacher
Indiana State University, Doctoral Candidate

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- Email [Identity Redacted] at [Email Redacted]

_____ I no longer want my child's scores used from the pretest and posttest for this study of mathematics vocabulary. Please remove his or her data from the study.

Parent signature ____ Date _____________

Print Student's name ____

Indiana State University Institutional Review Board, Office of Sponsored Programs
Terre Haute, IN 47809
Phone: (812) 237-8217
E-mail: irb@indstate.edu

APPENDIX D: INTERVIEW QUESTIONS FOR CONTROL GROUP TEACHER

School ____

Name____ Date ______________

1. Tell me a little about yourself.

2. Where did you attend college and what degree(s) do you have?

3. Please describe a typical day in your classroom.

4. How would you describe your method of teaching pre-algebra?

5. Do you believe it's important to teach vocabulary in mathematics?

6. Did you ever have training in the teaching of mathematics vocabulary? Please include professional development activities as well as teacher education classes.

7. Do you teach vocabulary in your classroom? If so, what methods do you use?

8. In what ways do you assess and evaluate mathematics vocabulary, both directly and indirectly in your classroom?

9. Are you aware of any trends linking the study of math vocabulary to high stakes testing?

10. Do you have any additional comments that you believe would help me in this study?

APPENDIX E: PRETEST & POSTTEST

The following pages contain the instructions to be read to the students for the pretests and posttests, the tests, the answer sheet and the answer keys.

PRETEST & POSTTEST

Directions to be read to the students prior to test session:

Read aloud only the text in bold. The text in italics is information for the test administrator.

Today you will be taking a pretest that will evaluate your knowledge of certain vocabulary words taken from the Indiana State Academic Standards for Mathematics. You will be given the entire class period to complete 50 multiple choice and matching questions that focus on mathematics vocabulary. Please use a number two pencil to mark your answers on the answer sheet provided. This test will not affect your grade in any way. You will not be graded on this test, in fact, you will not be told your score after the test has been graded. Please do your best so that this will be a valid study about vocabulary in eighth grade pre-algebra.

1. *Give each student a stapled cover sheet and answer sheet.*
2. *Instruct students to place their school name, period, name, and date on the appropriate blanks on the cover sheet. Have students check the appropriate blank, pretest, or posttest.*
3. *Instruct students to turn the page and tell them they are NOT to fill in the test number on the answer sheet.*

On the cover page, please fill in the blanks for your school name, period, first and last name and the date. Check the blank to the left of the word "Pretest." Turn the page. Please DO NOT fill in the test number on the answer sheet. This will be used by the Research Assistant so that the researcher will not know your identity.

Pass out the test packet and instruct the students they are NOT to write on this test.

Please DO NOT make any marks on this test. You will have 45 minutes to complete these questions. Please answer all questions on the answer sheet you have been provided. You may use the back of the cover sheet if you need scratch paper. When you have completed the test, keep the cover sheet attached to the answer sheet and turn it in on my desk along with the test. Are there any questions? You may begin.

MATHEMATICS

Vocabulary Test

Please DO NOT mark on this test copy in any way. Thanks!

You will have 45 minutes to complete this test. Choose the letter of the best answer for each question and **place your answer on your answer sheet**.

1. Look at this set of real numbers.

   $\left\{2.6667,\ \frac{2}{3}, \pi, \sqrt{15}, e\right\}$

   Which set below is the subset of **ALL** irrational numbers in the given set above?

   A. $\left\{2.6667,\ \frac{2}{3}\right\}$

   B. $\left\{\pi, \sqrt{15}, e\right\}$

   C. $\{2.6667, \pi, e\}$

   D. $\left\{\sqrt{15}\right\}$

2. Which of these numbers is an irrational number?

   A. $\sqrt{81}$

   B. $\sqrt{28}$

   C. $\sqrt{49}$

   D. $\sqrt{36}$

3. Write 9,320,000 in scientific notation.

   A. 9.32×10^7

   B. 932×10^4

   C. 9.32×10^4

   D. 9.32×10^6

4. Kelly is learning about rational and irrational numbers. What conclusion can she draw about the number 0.010110111011110111111...?

   A. It is rational because it repeats.

   B. It is rational because it terminates

   C. It is irrational because it neither repeats nor terminates.

   D. It is irrational because it repeats.

5. Find $\sqrt{144}$

   A. 14

   B. 15

   C. 13

   D. 12

6. Which of these is the slope of the line $y = \frac{3}{2}x - 1$?

   A. -1

   B. $\frac{2}{3}$

   C. $\frac{3}{2}$

   D. 1

7. Which of these is the equation of a line that has a slope of 2 and a y-intercept of $\frac{1}{3}$?

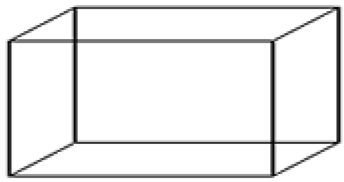
   A. $y = \frac{1}{3}x + 2$

   B. $x = \frac{1}{3}y + 2$

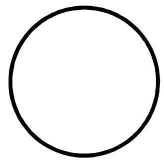
   C. $x = 2y + \frac{1}{3}$

D. $y = 2x + \frac{1}{3}$

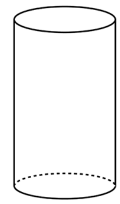
A.



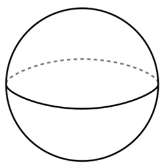
B.



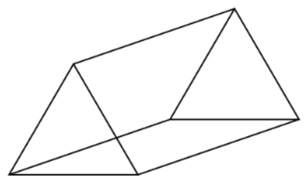
C.



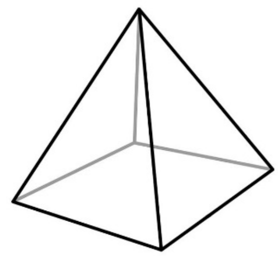
D.



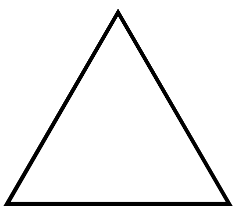
E.



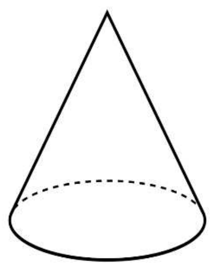
F.



G.



H.



I.

Match the shapes above with the following questions. Place the letter of the answer on your answer sheet.

8. Which shape above is a cylinder?
9. Which shape above is a sphere?
10. Which shape above is a rectangular prism?
11. Which shape above is a cone?
12. Which shape above is a pyramid?

13. A perfect number is a positive number that is equal to the sum of all positive integers that are submultiples of it, as 6, which is equal to the sum of 1, 2, and 3. Choose the perfect number below:

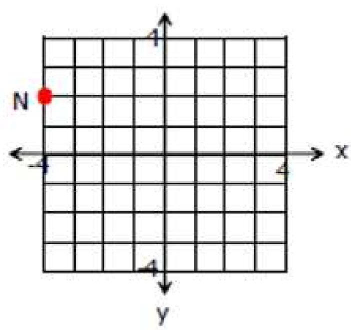
A. 8

B. 10

C. 12

D. 28

14. What will be the coordinates of the point N′ if the point N (-4, 2) is rotated 180° clockwise around the origin?



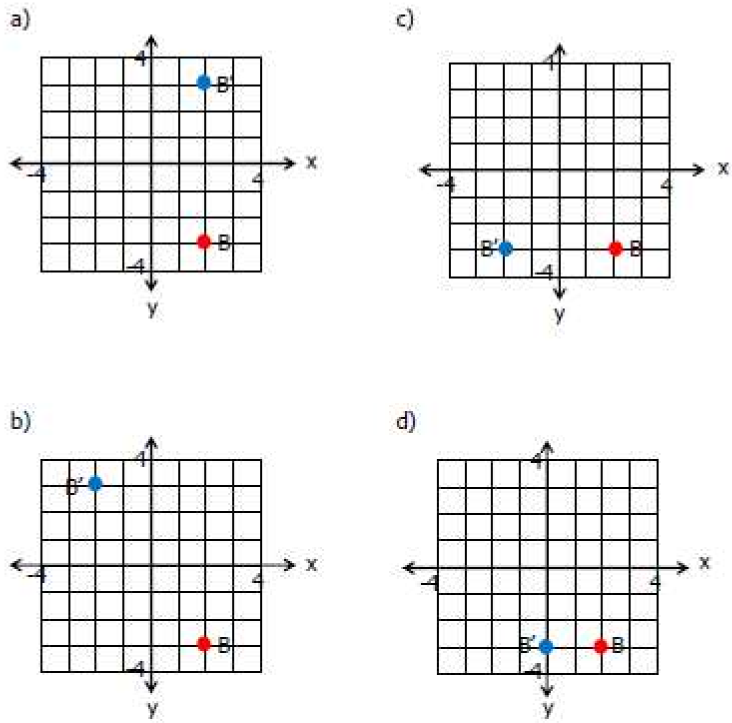
A. (4, 2)

B. (4, -2)

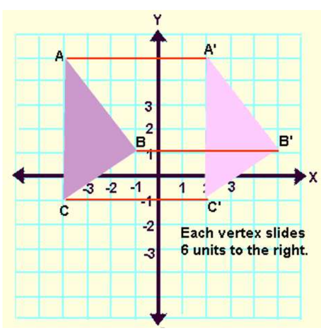
C. (-4, -2)

D. (-4, 2)

15. Choose the graph that shows the image of B (2, -3) after a reflection across the y-axis.



16. In the example below, notice how each vertex moves the same distance in the same direction.



In the graph above, which is illustrated?

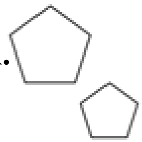
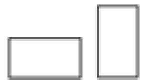
A. Rotation

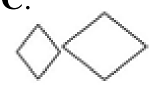
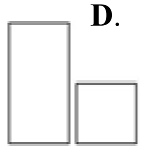
B. Translation

C. Reflection

D. Dilation

17. Which of these pairs of shapes is congruent?

A.  **B.** 

C.  **D.** 

18. Which of the following is true of *dilations*?

A. Dilations are enlargements or reductions in size.

B. A dilation is the same as a slide.

C. A dilation is the same as a rotation.

D. A dilation is the same as a reflection.

19. Which problem below would NOT be solved using the Pythagorean Theorem?

A. To get from point A to point B you must avoid walking through a pond. To avoid the pond, you must walk 34 meters south and 41 meters east. To the *nearest meter*, how many meters would be saved if it were possible to walk through the pond?

B. A baseball diamond is a square with sides of 90 feet. What is the shortest distance, to the *nearest tenth* of a foot, between first base and third base?

C. One of the fastest supercomputers in the world is NEC's Earth Simulator, which operates at a top-end of 40 teraflops (forty trillion operations per second). How long would it take this computer to perform 250 million calculations?

D. A suitcase measures 24 inches long and 18 inches high. What is the diagonal length of the suitcase to the *nearest tenth* of a foot?

20. Which of these questions involves bivariate data?

A. How many of the students in the class are female?

B. Is there a relationship between the number of females in the class and their scores in mathematics?

21. A cluster in math is defined as:

A. Numbers in a scatter plot

B. The difference between the lowest and highest values in a set of data

C. The number that occurs most often in a set of data

D. When data seems to be “gathered” around a particular value

22. Sometimes there is ONE piece of data that falls well outside a range of all the scores. This one piece of data is called:

A. the mean

B. the mode

C. the median

D. an outlier

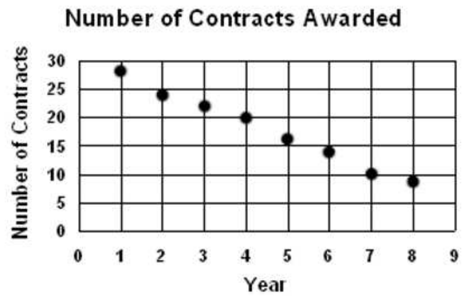
23. Which type of relationship might be shown in a scatter plot of data for the time of a long distance phone call and the cost of the call?

A. negative

B. positive

C. no relationship

24. Which type of relationship is shown in the graph?



A. negative

B. positive

C. no relationship

Match the following definitions with the words to the right for questions 25 – 31.

25.	When $x = ky$, what is the k called?	A. y-intercept
26.	A general term of an equation with two variables that gives a straight line when plotted on a graph	B. output
27.	Slope-intercept form of an equation	C. linear equation
28.	The point where a graph crosses the y-axis	D. preimage
29.	The value substituted into an expression or function	E. constant of proportionality
30.	The value that results from the substitution of a given value into an expression or function	F. $y = mx + b$
31.	The original figure in a transformation	G. input

32. Evaluate $\sqrt{\frac{1}{4}}$

A. 2

B. $\frac{1}{2}$

C. $\frac{1}{8}$

D. $-\frac{1}{2}$

33. What is the decimal equivalent of the rational number $\frac{6}{11}$?

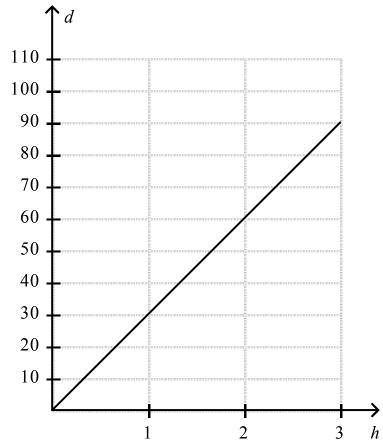
A. 0.54

B. $0.5\overline{4}$

C. $0.\overline{54}$

D. $1.8\overline{3}$

34. The graph shows the relationship between the number of hours *h* Greg has been driving and the total distance *d* he has traveled, in miles.



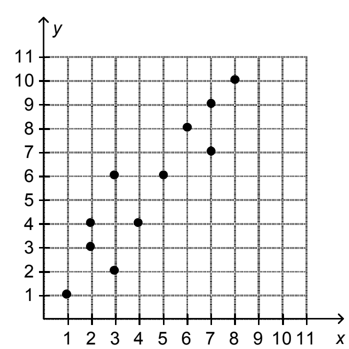
A. Greg is traveling at 90 miles per hour.

B. Greg is traveling at 30 miles per hour.

C. To find Greg's rate of speed, multiply the total number of hours driven by the total distance.

D. To find Greg's rate of speed, divide the total number of hours driven by the total distance.

35. Which statement *best* describes the pattern of association between the variables x and y shown in the scatter plot?



A. There is a positive, linear association between the two variables.

B. There is a negative, linear association between the two variables.

C. There is a positive, nonlinear association between the two variables.

D. There is no association between the two variables.

36. Determine if the relation represents a function.

x	y
0	-5
1	-1
2	3
3	6

A. The relation is a function.

B. The relation is not a function.

37. Which ordered pair is a solution to this system of equations?

$$2x + y = 14$$
$$3x - 2y = 7$$

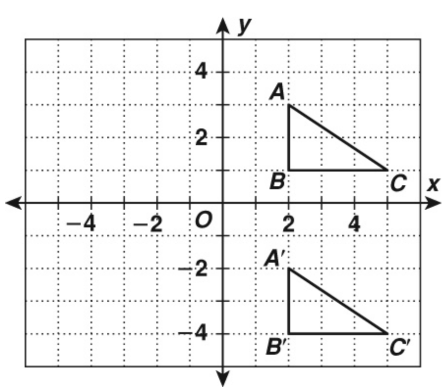
A. (4,6)

B. (5,8)

C. (5,4)

D. (4,5)

38. Which describes the transformation from the original to the image, and tells whether the two figures are similar or congruent?



A. translation, similar

B. translation, congruent

C. reflection, congruent

D. dilation, similar

39. A figure is dilated by a scale factor of 3. If the origin is the center of dilation, what is the image of a vertex located at $(3, 4)$?

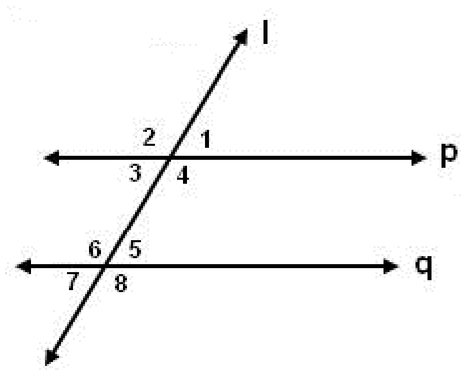
A. $1\frac{1}{2}$

B. (3, 12)

C. (9, 4)

D. (9, 12)

Suppose two parallel lines are cut by a transversal. Match the terms below as you refer to the diagram.



40. $\angle 1$ and $\angle 7$

41. $\angle 4$ and $\angle 8$

42. Line l

43. $\angle 3$ and $\angle 5$

44. $\angle 3$ and $\angle 6$

A. alternate interior angles

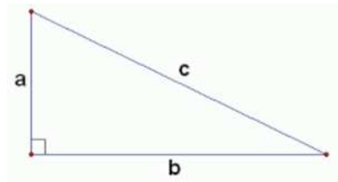
B. alternate exterior angles

C. corresponding angles

D. same-side interior angles

E. transversal

45. Which of the following statements does NOT match the diagram below?



A. This is a right triangle.

B. $a^2 + b^2 = c^2$

C. The hypotenuse is side c

D. The legs added together equal the length of side c

Match the following terms in # 47 through # 50.

46.	frequency	A. decimal number that ends
47.	relative frequency	B. a table organized in columns and rows to display two-variable data
48.	two-way table	C. number of times a value appears in a data set
49.	terminating decimal	D. the frequency of a specific data value divided by the total number of data values in the set
50.	non-terminating non-repeating	E. irrational number that never ends

Cover Page

School ____

Period _____

First Name ____

Last Name ____

Date ____________________

Check One

_____ Pretest   _____ Posttest

Please leave this page attached to the Answer Sheet.

Shade in a bubble for each of the multiple choice questions. For the matching questions, place the letter of the answer in the blank.

1. Ⓐ Ⓑ Ⓒ Ⓓ
2. Ⓐ Ⓑ Ⓒ Ⓓ
3. Ⓐ Ⓑ Ⓒ Ⓓ
4. Ⓐ Ⓑ Ⓒ Ⓓ
5. Ⓐ Ⓑ Ⓒ Ⓓ
6. Ⓐ Ⓑ Ⓒ Ⓓ
7. Ⓐ Ⓑ Ⓒ Ⓓ
8. Matching _____
9. Matching _____
10. Matching _____
11. Matching _____
12. Matching _____
13. Ⓐ Ⓑ Ⓒ Ⓓ
14. Ⓐ Ⓑ Ⓒ Ⓓ
15. Ⓐ Ⓑ Ⓒ Ⓓ
16. Ⓐ Ⓑ Ⓒ Ⓓ
17. Ⓐ Ⓑ Ⓒ Ⓓ
18. Ⓐ Ⓑ Ⓒ Ⓓ
19. Ⓐ Ⓑ Ⓒ Ⓓ
20. Ⓐ Ⓑ
21. Ⓐ Ⓑ Ⓒ Ⓓ
22. Ⓐ Ⓑ Ⓒ Ⓓ
23. Ⓐ Ⓑ Ⓒ
24. Ⓐ Ⓑ Ⓒ
25. Matching _____
26. Matching _____
27. Matching _____
28. Matching _____
29. Matching _____
30. Matching _____
31. Matching _____
32. Ⓐ Ⓑ Ⓒ Ⓓ
33. Ⓐ Ⓑ Ⓒ Ⓓ
34. Ⓐ Ⓑ Ⓒ Ⓓ
35. Ⓐ Ⓑ Ⓒ Ⓓ
36. Ⓐ Ⓑ
37. Ⓐ Ⓑ Ⓒ Ⓓ
38. Ⓐ Ⓑ Ⓒ Ⓓ
39. Ⓐ Ⓑ Ⓒ Ⓓ
40. Matching _____
41. Matching _____
42. Matching _____
43. Matching _____
44. Matching _____
45. Ⓐ Ⓑ Ⓒ Ⓓ
46. Matching _____
47. Matching _____
48. Matching _____
49. Matching _____
50. Matching _____

NOTE: Sign here **ONLY IF** you have changed your mind and you wish to withdraw your data from the study. ______________________________

Shade in a bubble for each of the multiple choice questions. For the matching questions, place the letter of the answer in the blank.

1.	Ⓐ Ⓑ Ⓒ Ⓓ	B		18.	Ⓐ Ⓑ Ⓒ Ⓓ	A		35.	Ⓐ Ⓑ Ⓒ Ⓓ	A
2.	Ⓐ Ⓑ Ⓒ Ⓓ	B		19.	Ⓐ Ⓑ Ⓒ Ⓓ	C		36.	Ⓐ Ⓑ	A
3.	Ⓐ Ⓑ Ⓒ Ⓓ	D		20.	Ⓐ Ⓑ	B		37.	Ⓐ Ⓑ Ⓒ Ⓓ	C
4.	Ⓐ Ⓑ Ⓒ Ⓓ	C		21.	Ⓐ Ⓑ Ⓒ Ⓓ	D		38.	Ⓐ Ⓑ Ⓒ Ⓓ	B
5.	Ⓐ Ⓑ Ⓒ Ⓓ	D		22.	Ⓐ Ⓑ Ⓒ Ⓓ	D		39.	Ⓐ Ⓑ Ⓒ Ⓓ	D
6.	Ⓐ Ⓑ Ⓒ Ⓓ	C		23.	Ⓐ Ⓑ Ⓒ	B		40.	Matching	B
7.	Ⓐ Ⓑ Ⓒ Ⓓ	D		24.	Ⓐ Ⓑ Ⓒ	A		41.	Matching	C
8.	Matching	C		25.	Matching	E		42.	Matching	E
9.	Matching	D		26.	Matching	C		43.	Matching	A
10.	Matching	A		27.	Matching	F		44.	Matching	D
11.	Matching	H		28.	Matching	A		45.	Ⓐ Ⓑ Ⓒ Ⓓ	D
12.	Matching	F		29.	Matching	G		46.	Matching	C
13.	Ⓐ Ⓑ Ⓒ Ⓓ	D		30.	Matching	B		47.	Matching	D
14.	Ⓐ Ⓑ Ⓒ Ⓓ	B		31.	Matching	D		48.	Matching	B
15.	Ⓐ Ⓑ Ⓒ Ⓓ	C		32.	Ⓐ Ⓑ Ⓒ Ⓓ	B		49.	Matching	A
16.	Ⓐ Ⓑ Ⓒ Ⓓ	B		33.	Ⓐ Ⓑ Ⓒ Ⓓ	C		50.	Matching	E
17.	Ⓐ Ⓑ Ⓒ Ⓓ	B		34.	Ⓐ Ⓑ Ⓒ Ⓓ	B				

NOTE: Sign here **ONLY IF** you have changed your mind and you wish to withdraw your data from the study. ___________________________________

APPENDIX F: CORRESPONDENCE WITH SCHOOL ADMINISTRATORS

In this appendix, you will find the correspondence with administrators from both the experimental and control schools requesting permission for the study to be conducted in their schools and their letters giving permission.

Dear Dr. [Identity Redacted]:

As you may recall, at the end of last school year I told you that I am currently working on my dissertation toward completion of my doctorate at Indiana State University. I am investigating whether a directed study of mathematics vocabulary has a significant effect on student performance on standardized multiple choice questions in Acuity. I have done extensive reading and a literature review investigating the study of vocabulary in mathematics. Using this information, I have developed a prescribed method for studying vocabulary that I wish to implement as part of the research project.

At this time, I am asking your permission and permission from Mr. [Identity Redacted] to implement this study during the 2015-2016 school year, upon IRB approval, from the time I receive IRB approval to May 2016. I am enclosing a copy of the letter that I plan to send home with students that will allow any student or parent/guardian to state that they do not want their student's data used in the study. As you will note in this letter, confidentiality of scores is a top priority.

[Identity Redacted] Middle School will provide students for the treatment group and [Identity Redacted] will provide students for the control group in the study. Because the students are adolescents having the capacity to comprehend the nature of the research activity, they will receive a consent form enumerating what their participation in the research would involve, a statement of minimal risk, and the option of nonparticipation with the ability to opt out at any time. Parents will receive a similar form to sign that would notify them of the study, the extent and conditions of their child's participation and the option of nonparticipation with the ability to opt out at any time if they consent to participate. In both the treatment and control groups, the identity of the students will be disguised when data is collected. All students will participate in the experiment as it is part of this year's curriculum and teaching for all students; however, only the data from students whose parents have agreed to let me use the data will be used.

To complete my application for the Institutional Research Board, I require a letter stating that if my research proposal is approved, you will allow me to have the treatment group for my research at [Identity Redacted] Middle School. If you have questions about my request, please contact me by phone at [Phone Number Redacted], by e-mail at [Email Redacted], or I can meet with you at your convenience.

Thank you for your consideration. I look forward to your reply.

Sincerely,

Marlane Waite

[Identity Redacted] Middle School Math Teacher
Indiana State University Doctoral Candidate

Dear [Identity Redacted]:

As you know, I am currently working on my dissertation toward completion of my doctorate at Indiana State University. I wish to do my research at [Identity Redacted] Middle School with students in my mathematics classes. I am investigating if a directed study of mathematics vocabulary has a significant effect on student performance on standardized multiple choice questions in Acuity. I have done extensive reading and a literature review investigating the study of vocabulary in mathematics. Using this information, I have developed a prescribed method for studying vocabulary that I wish to implement as part of the research project.

I have been assigned six pre-algebra classes with a total of 136 students. I will use data from three of my classes as the experimental group. The control group data will be from [Identity Redacted] Middle School. I have given you a copy of the Vocabulary Journal which shows how I will be studying vocabulary in mathematics with my students.

I am asking your permission and permission from Dr. [Identity redacted] to implement this study in the fall of the 2015-2016 school year from IRB approval to May 2016. I am enclosing a copy of the letters that I plan to send home with students that will allow any student or parent/guardian to state that they do not want their student's data used in the study. As you will note in these letters, confidentiality of scores is a top priority. Please let me know if there is anything in either correspondence that you wish for me to change.

Because the students are adolescents having the capacity to comprehend the nature of the research activity, they will receive a consent form enumerating what their participation in the research would involve, a statement of minimal risk, and the option for nonparticipation with the ability to opt out at any time. Parents will receive a similar form to sign that would notify them of the study, the extent and conditions of their child's participation and the option for nonparticipation with the ability to opt out at any time if they consent to participate. Randomly selected students from [Identity Redacted] Middle school will be in the treatment group and their identity will be disguised when data is collected as will the identity of students in the control group who are from a nearby county. All students who are in the treatment group are from [Identity Redacted] Middle school and will participate in the experiment as it is part of this year's curriculum and teaching for all students; however, only the data from students whose parents have agreed to let me use the data will be used.

Because the research project will not be conducted at a facility owned and operated by Indiana State University, I am required to obtain a letter from you to be submitted on letterhead stationery and should contain the following:

- agreement for the study to be conducted
- identification of someone at the site who will provide information about the appropriateness for its population
- assurance of adequate capabilities to perform the research as approved by the IRB
- assurance that facility personnel involved in data collection have appropriate expertise and will follow IRB approved procedures

If you have questions about my request, please contact me.

Thank you for your consideration. I look forward to your reply.

Professionally,

Marlane Waite

[Identity Redacted] Middle School Math Teacher
Indiana State University Doctoral Candidate

[Identity Redacted]

[Identity Redacted]

[Identity Redacted]

Central Office

[Identity Redacted]

6/27/16

To whom it may concern,

This letter is to verify that Marlane Waite has been authorized to conduct a study in her math courses here at [Identity Redacted]

Mrs. Waite serves as the designee to provide information about the appropriateness for our population. She has done this by identifying the work to be done and outlining the potential value the work may have for middle school students.

Mrs. Waite is also working within a building that has adequate capabilities to perform the research as approved by the IRB.

In addition, Mrs. Waite holds the appropriate expertise in data collection and has agreed to follow IRB approved procedures in collected said data.

We look forward to hearing what the results can tell us about vocabulary work as it relates to math instruction.

If you have any questions, please don't hesitate to call.

Sincerely,

[Identity Redacted]

[Image Redacted]

Dear [Identity Redacted]:

As we discussed on the phone this past summer, I am currently working on my dissertation toward completion of my doctorate at Indiana State University. We discussed using three eighth-grade math classes at [Identity Redacted] Middle School with students in my mathematics classes. I am investigating whether a directed study of mathematics vocabulary has a significant effect on student performance on standardized multiple choice questions in Acuity. I have done extensive reading and a literature review investigating the study of vocabulary in mathematics. Using this information, I have developed a prescribed method for studying vocabulary that I wish to implement as part of the research project.

At this time, I am asking your permission and permission from Mr. [Identity Redacted] to implement this study during the 2015-2016 school year, upon IRB approval, until May 2016. I am enclosing a copy of the letter that I plan to send home with students that will allow any student or parent/guardian to state that they do not want their student's data used in the study. As you will note in this letter, confidentiality of scores is a top priority.

Because the students are adolescents having the capacity to comprehend the nature of the research activity, they will receive a consent form enumerating what their participation in the research would involve, a statement of minimal risk, and the option of nonparticipation with the ability to opt out at any time. Parents will receive a similar form to sign that would notify them of the study, the extent and conditions of their child's participation and the option of nonparticipation with ability to opt out at any time if they consent to participate. The identity of the students will be disguised when data is collected, and only the data from students whose parents have agreed to let me use the data will be used.

To complete my application for the Institutional Research Board, I require a letter stating that if my research proposal is approved, you will allow me to have the control group for my research at [Identity Redacted] Middle School. If you have questions about my request, please contact me by cell phone at Phone Number Redacted], by e-mail at [Email Redacted], or I can meet with you at your convenience.

Thank you for your consideration. I look forward to your reply.

Sincerely,

Marlane Waite
[Identity Redacted] Middle School Math Teacher
Indiana State University Doctoral Candidate

Dear [Identity Redacted]:

As we discussed on the phone this past summer, I am currently working on my dissertation toward completion of my doctorate at Indiana State University. We discussed using three eighth grade math classes from [Identity Redacted] Middle School for my control group. I am investigating if a directed study of mathematics vocabulary has a significant effect on student performance on standardized multiple choice questions in Acuity. I have done extensive reading and a literature review investigating the study of vocabulary in mathematics. Using this information, I have developed a prescribed method for studying vocabulary that I wish to implement as part of the research project.

I am asking your written permission (and have contacted [Identity Redacted]) to implement this study in the 2016-2017 school year upon IRB approval. I am enclosing a copy of the letters that I plan to send home with students, pending your approval, which will allow any student or parent/guardian to state that they do not want their student's data used in the study. As you will note in these letters, confidentiality of scores is a top priority. Please let me know if there are any changes you wish for me to make in this correspondence.

Because the students are adolescents having the capacity to comprehend the nature of the research activity, they will receive a consent form enumerating what their participation in the research would involve, a statement of minimal risk, and the option for nonparticipation with the ability to opt out at any time. Parents will receive a similar form to sign that would notify them of the study, the extent and conditions of their child's participation and the option for nonparticipation with ability to opt out at any time if they consent to participate. The identity of the students will be disguised when data is collected and only the data from students whose parents have agreed to let me use the data will be used. Your school will provide the control group for my study and students at [Identity Redacted] Middle School will provide the treatment group.

Because the research project will not be conducted at a facility owned and operated by Indiana State University, I am required to obtain a letter from you to be submitted on letterhead stationery and should contain the following:

- agreement for the study to be conducted
- identification of someone at the site who will provide information about the appropriateness for its population
- assurance of adequate capabilities to perform the research as approved by the IRB
- assurance that facility personnel involved in data collection have appropriate expertise and will follow IRB approved procedures

If you have questions about my request, please contact me.

Thank you for your consideration. I look forward to your reply.

Professionally,

Marlane Waite

[Identity Redacted] School Math Teacher
Indiana State University Doctoral Candidate

[Information Redacted]

To whom it may concern,

This letter is to verify that Marlane Waite, a doct [Identity Redacted] diana State University, has been authorized to recruit participants from [Identity Redacted] School's pre-algebra classes to serve in a control group for a study ab cabulary.

[Identity Redacted] our guidance counselor, serves as the designee to provide information about the appr population. In addition to his duties as guidance counselor for [Identity Redacted] School, he is also familiar with students' and teachers' schedules and ation to Mrs. Waite such as class lists and retrieving addresses for the Parent Consent forms.

[Identity Redacted] School has adequate capabilities to perform the research as approved by the IRB and will work with Mrs. Waite to assist her in data collection and to perform her research as approved by the IRB.

Mrs. Waite has my permission to perform three unannounced visits to the class room of the control group teacher for the purpose of observing and to interview this teacher at the completion of this study in December 2016. I understand that Mrs. Waite will use this information for the sole purpose of analyzing it for her study, looking for patterns to promote better understanding of any found differences in student performance that may be attributable to the intervention.

I look forward to reading the results of this study at its conclusion.

If you have any questions, please don't hesitate to call.

Sincerely,

[Identity Redacted]