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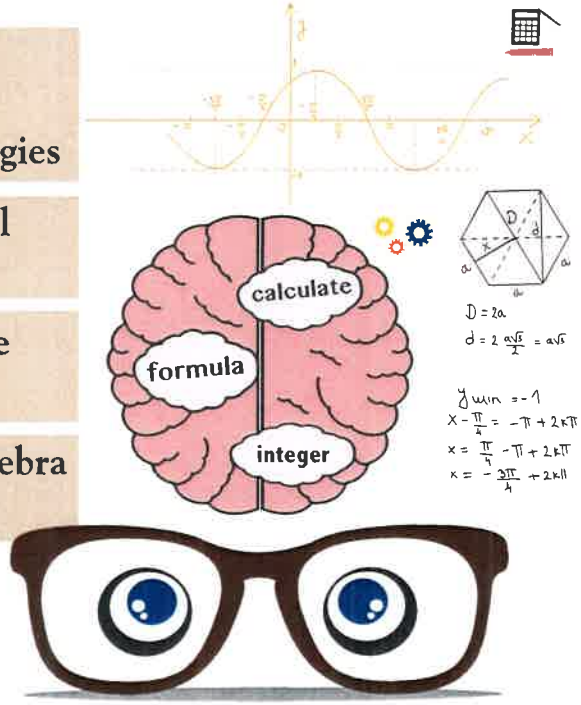
The Effects of Vocabulary Learning Strategies in Mathematical Instruction on Ninth-Grade Students' Coordinate Algebra Achievement



BY ANNETTE PAYNE AND LINA B. SOARES

Abstract

The purpose of this study was to investigate if adding the vocabulary learning strategies of an interactive word wall and graphic organizers to mathematical instruction was an effective method to increase student achievement in mathematics for two ninth-grade coordinate algebra classes. The 45 participants in the study were members of two co-taught ninth grade coordinate algebra classes in the Southeastern United States. This study used a quasi-experimental design with a pre-assessment/post assessment. An analysis of covariance (ANCOVA) was used to compare the achievement levels of the two classes, as measured by the post assessment. The results did not show a significant difference between the post assessment scores of the experimental class using graphic organizers and an interactive word wall compared to the control class that did not. The results of this study may be important to teachers as they implement the Common Sore State Standards, the Common Core Georgia Performance Standards, and the Mathematical Practice Standards.

The Common Core Georgia Performance Standards (CCGPS) (2014c, p. 45) require secondary students to be able to complete the following coordinate algebra problem:

> Antonio and his friend Brittany were at summer math camp where the counselors had drawn a large coordinate plane on the gym floor. Antonio challenged Brittany to mirror him as he walked in the first quadrant.
>
> *Map both of their travels on the same coordinate plane.*
>
> Antonio began at (2, 1) and walked to (3, 5); Brittany decided to begin at (–2, 1), then tried to mirror Antonio by walking to (–3, 5). Antonio jumped to (5, 5) and side-stepped to (4, 3); Brittany jumped to (–5, 5) then side-stepped to (–4, 3). Antonio returned to (2, 1) and Brittany returned to (–2, 1).
>
> *1. Did Brittany mirror Antonio?*
> *a. If you answered no, identify the incorrect*

coordinates Brittany used and find the correct coordinates. Explain your decision and identify the line of symmetry she should have used as a mirror. How did you know that this should have been the line of symmetry?

b. If you answered yes, identify the line of symmetry Brittany used as a mirror. How did you know it was the line of symmetry?

Introduction

Beliveau (2001) stated that "the language of mathematics is comparable to a foreign language; math is a combination of symbol, numbers and words" (p. 2). For many students who struggle in math, math does resemble a foreign language. The coordinate algebra problem above presents the dilemma that many students encounter. Words such as quadrant, line of symmetry, and coordinate plane are examples of content-specific vocabulary that can inhibit students from solving the math problem. It is not uncommon for a secondary math teacher to hear, "I think I could solve the problem if I knew what all the words mean."

Kovarik (2010) posits that math is not only a discipline of symbols and numbers, but it is a discourse of spoken and written words that students must understand to apply in order to compute and apply their math skills. Kovarik (2010) further acknowledges that when students struggle with word problems or find difficulty articulating the procedures needed to solve word problems, it is due to the lack of vocabulary knowledge to understand what is expected. Marzano (2004) echoes this premise by finding that when students are able to speak the mathematical language, their math achievement scores improve as much as 33%. In conjunction, when vocabulary instruction has been implemented with underachieving math students, Gifford and Gore (2008) found that achievement gains on the math portion of standardized tests improved as much as 93%. Both of these studies imply that achievement in mathematics is linked to content-area literacy and the ability to understand the language of mathematics reflects the importance of academic vocabulary knowledge.

Shanahan and Shanahan (2008) have explicated that content-area teachers need to move beyond the generalist notion of literacy learning and explore how to teach literacy in their disciplines. Communication is the very essence of our society and language is the vehicle that drives the communication. Math is a language and mathematicians have been among the first to recognize its communicative value (Wakefield, 2000). In fact, the National Council of Teachers of Mathematics (NCTM) published *Principles and Standards for School Mathematics* in 2000 which contains the following communication standards:

- Organize and consolidate their mathematical thinking through communication.
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.
- Analyze and evaluate mathematical thinking and strategies of others.
- Use the language of mathematics to express mathematical ideas precisely. (p. 348)

Clearly, the amount of attention that NCTM placed on language and communication in mathematics highlights the need to implement vocabulary instruction. Yet, despite the emphasis on communication in mathematics, many math teachers still see mathematics as a set of algorithms devoid of oral or written communication. Research has pointed to content teachers' perception that literacy is a low priority (Fisher & Ivey, 2005); content literacy is an afterthought or product of good teaching, not a way to teach for most secondary mathematics teachers. This view in mathematics can no longer be acceptable as the Common Core State Standards (CCSS) (National Governors Association & Council of Chief State Officers, 2010), the Common Core Georgia Performance Standards (CCGPS) (Georgia Department of Education, 2013), and the Mathematical Practice Standards (Common Core State Standards Initiative, 2015) emphasize that students must demonstrate the ability to perform procedural skills to solve math problems and provide justification for the procedure. Justification is required to further demonstrate the cognitive understanding that enables students to synthesize solutions on similar problems and not through simple use of an algorithm (Georgia Department of Education, 2013). However, justification is only possible when the language of mathematics is understood.

Statement of the Problem

When the Partnership for Assessment of Readiness for College and Careers (PARCC) released the performance level descriptors (PLDs) in mathematics (PARCC, 2013a), highly complex questions based on the PLDs involved higher linguistic demands in an item stem. Such demands now require students to analyze content, construct formal mathematical arguments, and construct extended written responses (PARCC, 2013b). PLDs are used to measure the achievement levels under the Common Core State Standards for Mathematics (PARCC, 2013c). Subsequently in 2014, the Department of Education in Georgia released their new assessment system called Georgia Milestones, and this new assessment adheres to the same high expectations and rigor of the PARCC (2013a) assessments. Problem-solving is required to show mathematical achievement, but the answer alone is not enough to prove achievement anymore. Communication of the reasoning and procedures used to solve the problem is required to show understanding and justify achievement. Highly complex assessment items demand vocabulary knowledge – the basis for the effective mathematical language needed to achieve in math. As a result, the need to incorporate vocabulary instruction in math classrooms is critical.

The purpose of this study was to incorporate vocabulary learning strategies into a ninth- grade coordinate algebra classroom in order to determine if the vocabulary instruction affected the students' mathematical achievement. The study combined the vocabulary learning strategies of graphic organizers (Zollman, 2009) and interactive word walls (Harmon, Wood, Hedrick, Vintinner, & Willeford, 2009). Research has shown these methods to be positively perceived and linked to both vocabulary growth and achievement gains. From this stance, the following research question guided this study: *Does the incorporation of the vocabulary learning strategies of interactive word walls and graphic organizers into mathematical instruction affect ninth grade students' coordinate algebra achievement?*

The Importance of Vocabulary Knowledge in Mathematics Achievement

Achievement in mathematics starts with a solid foundation of mathematical understandings, and students' poor mathematical vocabulary knowledge consistently inhibits mathematical achievement. Because many secondary teachers view themselves as content experts and not reading teachers (Fisher & Ivey, 2005; Shanahan & Shanahan, 2008), the idea of teaching vocabulary is often limited to a dictionary definition. In mathematics, dictionary definitions are particularly troublesome because of the possibility of multiple mathematical definitions for the same object that leads to different mathematical activities depending on the concept that is being addressed (Gough, 2007; Morgan, 2005). The confusion over multiple definitions and the neglect of meaningful classroom vocabulary instruction leads to only a surface understanding and the mathematics vocabulary is never truly understood (Kouba, 1989; Monroe & Orme, 2002). To compound the problem, the language of mathematics is made up of technical vocabulary words and sub-technical vocabulary words. Technical vocabulary words are the words that have only one meaning and represent a concept such as rhombus. Sub-technical vocabulary words such as degree are those words that have other meanings outside of mathematics that can cloud the mathematical meaning (Gough, 2007; Leung, 2005; Monroe & Orme, 2002; Pierce & Fontaine, 2009).

To counter the difficulty with technical math vocabulary, Beck, McKeown, and Kucan (2002) recommend teachers provide "student-friendly explanations" (p. 35) of math words, emphasizing the word meaning and modeling how the words are used in everyday language. The authors further suggest that teachers engage their students in varied vocabulary strategies because students need multiple opportunities to learn math words. In addition, Harmon, Hedrick, and Wood (2005) emphasize the importance in building students' conceptual knowledge of content vocabulary in a math classroom because "...the words are labels for important concepts" (p. 265). When teachers take the time to build students' conceptual understanding of math terms, they move beyond a surface level of understanding to one of greater depth. The premise is that the more mathematical concepts students understand, the more that math makes sense.

Others have weighed in on the power of discussion and vocabulary learning. Carlisle, Fleming, and Gudbrandsen (2000) have found that when students are given opportunities to engage in active discussions about content vocabulary words, the discussion activity allows for higher levels of cognitive processing. Additionally, research has shown that Web 2.0 technology strengthens vocabulary knowledge. For example, Matthews (2010) investigated middle grade students' ability to problem solve after participation in an academic language instructional program that met twice a week. Using blogging technology, Matthews found the students increased their math content knowledge and everyday usage of mathematics vocabulary because the threaded discussion format permitted the students to practice their math vocabulary.

Vocabulary's Importance to Oral Communication

Content literacy in mathematics requires the use of oral communication. Communication is formed by words which places a fundamental importance on vocabulary knowledge. A student's vocabulary knowledge when entering school is a strong predictor of later reading achievement (Pullen, Tuckwiller, Konold, Maynard, & Coyne, 2010). Low reading achievement levels have been related to low academic performance and one of the key factors of reading achievement is vocabulary knowledge (U. S. Department of Education, 2010/2011). In addition, research has found that engaging students in meaningful oral expression activities can help students, especially those with low reading levels, internalize vocabulary (Baumann, Ware, & Edwards, 2007; Firmender, Gavin, & McCoach, 2014; Francis & Simpson, 2003).

The power of oral expression as a means to promote mathematical understanding has long been advocated for students of all grade levels. Cooke and Adams

(1998) posit that students need time to interact and "talk math" in a supportive environment to discuss math concepts and build problem solving skills. Roti, Trahey, and Zerafa (2000) provide support for this assertion. The researchers found that when students are given time to talk about the language in word problems, not only do students build stronger problem-solving skills, they build confidence as well.

The CCSS (2010) addresses the importance of communication in learning mathematics in the Introduction by stating, "One hallmark of mathematical understanding is the ability to justify . . . a student who can explain the rule understands the mathematics and may have a better chance to succeed at a less familiar task . . ." (p. 4). This statement emphasizes the role that discussion is to learning in mathematics. To reinforce the premise that talk is learning mathematics, Chapin, O'Connor, and Anderson (2009) have developed five teaching strategies to enhance talk in the mathematics classroom. The authors suggest that teachers first apply the strategy of revoicing – repeating a student's response in the math classroom and then permitting the student to verify if the words used were correct. Next, the teacher asks a student to restate another student's reasoning, followed by asking a student to apply their own reasoning to another student's reasoning. Chapin, O'Connor, and Anderson (2009) further suggest that math teachers pose questions to promote thinking and discussion, such as *How did you reach that conclusion?; Do you care to elaborate?; and Would someone else like to add-on to this discussion?* Finally, the authors recommend that math teachers promote a learning environment where students feel comfortable to discuss out loud and to demonstrate the ability to wait; i.e. permitting students time to compose their math reasoning before interrupting and moving to the next student.

Vocabulary's Importance to Written Communication

The multiple dimensions of knowing a vocabulary word range from the least in-depth, which is no knowledge, to the greatest in-depth, which is the ability to use and remember a word (Christ & Wang, 2011; Francis & Simpson, 2003; Qian & Schedl, 2004). Most students agree that truly knowing a word means that they can use it when writing (Francis & Simpson, 2003). Just doing mathematics does not lead to acquisition of the language of mathematics. The language of mathematics is built upon logical statements along with their negations. The outside world does not adhere to these conventions and the meanings of outside terms are not the same as the more-technical meaning in mathematics (Epp, 1999; Monroe & Orme, 2002; Pierce & Fontaine, 2009). The logical thinking needed in mathematics is not innate for most people and must be taught. In fact, the NCTM (2000) posits that written communication must be nurtured because students' misconceptions are sometimes difficult for teachers of mathematics to understand and without a firm understanding of students' misconceptions the difficulty in overcoming these misconceptions is extreme. According to Epp (1999), vocabulary knowledge is required to interpret the information, record information to solve, and explain the results. Writing is a way to see what students are thinking when problem-solving (Pugalee, 2001).

In a mixed-methods study conducted by Kostos and Shin (2010), the researchers found that 16 second-grade students' mathematical vocabulary usage increased with journal writing. Moreover, the qualitative results showed the students felt that journal writing improved their skill development. In a study conducted with 12 middle grade participants, Lim and Pugalee (2004) found similar results. The researchers concluded that the 12 participants in the study increased their mathematical vocabulary usage to explain the problem-solving process from the first semester to the second semester based on the repeated process of journal writing.

The Importance of Graphic Organizers in Mathematics Achievement

Graphic organizers have been used effectively to improve written communication. Yet, research also shows that graphic organizers are effective tools for vocabulary instruction in math classrooms (Baumann et al., 2007; Lucas & Goerss, 2007; Zollman, 2012) because graphic organizers are a way to establish relationships among words. In conjunction, Francis and Simpson (2003) explicate that graphic organizers scaffold students' thinking about vocabulary learning in math from simple memorization of a definition to actually knowing, remembering, and applying the words.

At the elementary school level, graphic organizers are a common instructional tool for all subject-related concepts; however, graphic organizers have been shown to aid in secondary math classrooms as well. Ives (2007) conducted a two-group comparison experimental design to study using graphic organizers in a secondary algebra classroom for students with learning disabilities. The findings from a posttest given at the end of the study showed that the addition of a graphic organizer with direct instruction resulted in a higher performance for the experimental group who used the graphic organizer. Additional findings showed the experimental group's conceptual understanding was maintained on a second posttest given two to three weeks later.

The use of concept maps for vocabulary instruction in math classrooms have been found to enhance the depth of knowledge needed for mathematical understanding (Francis & Simpson, 2003; Kucan, Trathen, & Straits, 2007). Concept maps permit students to identify the commonalities among math terms, rather than working with unconnected words that do not build strong mathematical knowledge. In a qualitative study by Lucas and Goerss (2007), the researchers used the common traits idea with separate groups of ninth-grade geometry students and pre-service teachers. The participants were put in groups of three or four and asked to categorize a group of math words. Not all participants constructed the same categories, but each group was able to make vocabulary connections to their respective categories. Additionally, the results from a survey revealed that both groups felt that the activity was beneficial to strengthen their mathematical conceptual understanding.

The Importance of Interactive Word Walls in Mathematics Achievement

Word walls take the idea of graphic organizers one step further. The strength of the interactive word wall is its interactivity. Vocalizing important words in the proper syntax aids in the understanding of the meaning and allows the teacher to clarify inappropriate usage (Francis & Simpson, 2003). Interactive word walls are visual displays of words with designs including separate walls for different purposes or one wall that can be used for multiple purposes. Although an interactive word wall can be an appropriate scaffolding tool, the end result should be creating independence instead of reliance (Brabham & Villaume, 2001).

Kucan et al. (2007) developed a collaborative effort to enhance secondary vocabulary instruction which used visual displays of words that fit into categories. This idea combined the concept of an interactive word wall and a graphic organizer by turning the interactive word wall into a form of graphic organizer. Yates, Cuthrell, and Rose (2011) advanced the interactive word wall even further by making an eighth grade hallway into an interactive word wall that contained vocabulary aligned to the eighth grade state curriculum in English, science, social studies and math. The increase in state assessment scores was attributed to the use of the interactive word walls. In addition, Latham (2011) conducted a qualitative study that involved four eighth-grade teachers along with their 62 students and 12 students participated in pre/post interviews. The four teachers represented the following subject areas: language arts, science, social studies and mathematics. The school was located in the Southeastern region of the U.S. in an urban area that is predominantly Hispanic and Black. The teachers were given professional development for implementing interactive word wall activities but the actual word choices were left to the students. The conclusions of this study were (1) positive perceptions of the interactive word wall by teachers and students in all areas except math (the math survey was given at a time when the other students were outside playing); (2) teachers embraced the interactive word wall as their comfort level grew; (3) student motivation was linked to their ability to choose interactive word wall activities; and (4) student vocabulary knowledge broadened and deepened.

Summary

From a review of the literature, vocabulary knowledge has been found to improve mathematical achievement. Teachers' verbal communication of mathematical language, coupled with engaging students in meaningful oral expression activities have also been linked to students' ability to internalize vocabulary and improve mathematical achievement. Additionally, written assignments with explicit instructions in math encourage mathematical content knowledge. The review of literature has further shown that the implementation of graphic organizers improve mathematical language development and conceptual knowledge. Additionally, the use of graphic organizers results in higher performance and retention of mathematical conceptual knowledge for secondary students with learning disabilities. Finally, when graphic organizers have been implemented in the form of an interactive hallway word wall in one middle school, an increase in state assessment scores were attributed to this strategy.

Method

A quasi-experimental design with a pre-assessment/post assessment was used for this study. The study occurred during a six-week period in spring 2015 and consisted of a treatment and a control group. Both the treatment and control groups studied the linear and exponential functions unit from CCGPS coordinate algebra course (Georgia Department of Education, 2014b). All learning targets and classroom instruction of the mathematics curricula were the same for both groups. However, the treatment group created classroom word wall displays using graphic organizers to develop the definitions and meanings of mathematical vocabulary. Conversely, the control group just wrote down the definitions of the mathematical terms of study. The level of interactivity with the word wall was the independent variable. The dependent variable was mathematics achievement. The pre-assessment was used as a covariate in this design.

Participants

The participants in the study were members of two co-taught ninth-grade coordinate algebra classes in the Southeastern United States. The classes were taught

by the researcher and a co-teacher during spring 2015. All 57 participants were in a coordinate algebra support class during fall of 2014. Specifically, the participants included 14 students who failed to pass the eighth-grade mathematics portion of the Criterion-Referenced Competency Test (CRCT) in the spring 2014 and summer 2014 administrations, eight students who failed the eighth-grade mathematics portion during the spring 2014 administration of the CRCT but did pass during the summer 2014 administrations, four students who passed the CRCT-M alternate assessment for eligible students who received special education services, and eight students who were repeating the course for the second or third time.

The two intact classes served as the treatment and control groups, and the treatment group was randomly assigned by the researcher based on a coin toss. The treatment group (2nd period class) had 24 participants with an ethnic composition of 59% African American, 26% white, and 15% multi-racial; this class contained 14 males and 13 females. The ethnic composition of the 21 participants in the control group (4th period class) was 56% African American, 37% white, and 7% multi-racial; this class contained 22 males and eight females.

Instrument and Materials

Tests. Each student was given an identical teacher compiled pre-assessment/ post assessment using the Georgia's Online Assessment System (OAS) question bank. This test bank was aligned to the state-mandated curriculum and consisted of the types of questions (multiple choice, open response, and constructed response) that appear on the state assessment. All available multiple choice questions that represented the target standards were chosen and after carefully considering the proportion of questions for each standard, the open response and constructed response questions were chosen to balance out the test. The multiple choice and open response items were worth "1" point each and were either right or wrong, but the constructed response item was worth four points and was graded based on the general rubric provided with the question (see Appendix A). According to the Georgia Department of Education (2015) regarding OAS, the test bank is provided for Georgia state teachers to use in order to construct classroom assessments that will enhance instruction and promote student achievement. Because the test items are aligned to the state mandated curriculum, this alignment ensures the validity of the assessment. The instrument reliability is ensured by having only one correct answer for the multiple choice items and rubrics with exemplars provided for the open response questions.

The pre-assessment/post assessment consisted of 22 multiple choice questions, seven open response questions, and one constructed response question. A perfect score was defined as 33 out of 33 or 100 percent. The pre-assessment was given to each group at the beginning of the study to determine a baseline of knowledge over the function standards from the linear and exponential functions unit of the CCGPS coordinate algebra course (Georgia Department of Education, 2014b) and an identical post assessment was given to each group at the conclusion of the study to measure growth in mathematics achievement.

Curriculum. The source of the curriculum was the linear and exponential functions unit from CCGPS coordinate algebra course in the Georgia Department of Education Frameworks (Georgia Department of Education, 2014b). This specific study focused specifically on the interpreting functions standards. These functions standards provided the foundation needed to understand algebraic functions and were imperative to success in future courses.

Word wall. A word wall was created in the classroom. The word wall will consisted of words only (see Appendix B) and contained graphic organizers (see Appendix C and Appendix D) created by the treatment group. The two instructional tools were created to help define the word or help to show situations when the word would be used in the context of the math topics addressed in the linear and exponential functions unit of the CCGPS coordinate algebra course (Georgia Department of Education, 2014b).

Procedure

The study concentrated on raising mathematics achievement with the incorporation of an interactive word wall in the treatment class. The control group and the treatment group took the pre-assessment in the beginning of week one. All learning targets, vocabulary, and classroom instruction of the mathematics curriculum were the same each week in both classes. During week one, week three, and week five, all students were given time to define the vocabulary words, but while the control group just wrote down definitions, the treatment group created classroom word wall displays using graphic organizers to develop the definitions and meanings.

For week two and week four, both groups were given class time to study their vocabulary, but at the end of each week, the treatment group participated in study time using the interactive word wall to play fly swatter vocabulary. The teacher was responsible for posting the selected vocabulary words on the interactive word wall while the students were rotated in groups and competed using a fly swatter to swat the correct word after a definition or example was given. A post assessment was given at the end of week six.

TABLE 1

ANCOVA Results and Descriptive Statistics for Post assessment Scores by Groups and Pre-assessment Scores

Group	Post assessment			
	Observed Mean	Adjusted Mean	SD	n
Control	22.6667	23.164	15.62	21
Treatment	23.8333	23.398	11.47	24

Source	SS	Df	MS	F
Pre-assessment	718.079	1	718.079	4.196*
Group	.609	1	.609	.004
Error	7187.921	42	171.141	

Note. R2 = .093, Adj. R2 = .049, adjustments based on Pre-assessment mean = 16.2000. Homogeneity of regression tested and not significant: F = 0.595, p >.05. Pre-assessment regression coefficient = 0.644*.
* p < .05
Note. The observed mean, adjusted mean, and SD are based on percentage scores, not number correct.

Results

Data Analysis

The research question that guided the study was: Does the incorporation of the vocabulary learning strategies of interactive word walls and graphic organizers into mathematical instruction affect ninth grade students' coordinate algebra achievement? Descriptive statistics (means and standard deviations) were calculated for the pre-assessment and post assessment scores for both the treatment and control group. An analysis of covariance (ANCOVA) was used to compare the achievement levels of the two classes, as measured by the post assessment, to determine if a significant difference existed between the classes following the treatment. The pre-assessment scores were used as a covariate to ensure that classes were statistically equivalent at the beginning of the study in terms of their mathematical achievement. All tests were performed at the .05 level of significance.

Findings from Data Analysis

From data analysis, the control group's pre-assessment mean was 15.4% with a standard deviation of 7.4, while the treatment group's pre-assessment mean was 16.9% with a standard deviation of 5.3. An ANCOVA with factor covariance interactions indicated no interaction between the groups and the pre-assessment ($F(1, 41) = .595$, $p > .05$). Since an interaction did not exist, the interaction was removed and a one-way analysis of covariance (ANCOVA) was conducted. The ANCOVA results showed a significant relationship between the pre-assessment and the math achievement measured by the post assessment ($F(1, 42) = 4.196$, $p < .05$) but when the post assessment scores were analyzed between groups, a significant difference did not exist between the groups ($F(1, 42) = .004$, $p > .05$). The results are shown in Table 1.

The regression coefficient of .644 demonstrated a positive relationship between pre-assessment scores and the post assessment scores. However, the mean difference of the post assessment for the control group and the treatment group at the .05 significance levels were not significant using the pairwise comparisons.

Discussion of Research Findings

This research investigated the incorporation of the vocabulary learning strategies of interactive word walls and graphic organizers into mathematical instruction to determine if an effect on ninth-grade students' coordinate algebra achievement would result. A quasi-experimental design with a pre-assessment/post assessment was used for this study with 45 ninth grade students. The data were collected by giving each student an identical teacher compiled pre-assessment/post assessment using the Georgia's Online Assessment System (OAS) question bank.

Unlike the research of Ives (2007) who findings demonstrated that secondary students with learning disabilities who use graphic organizers in a secondary algebra classroom made significant gains, this study failed to see a significant difference in mathematics achievement between the treatment and control groups. Unfortunately, the results of this study also did not link mathematics achievement to the use of graphic organizers as had been projected based on the research studies involving students that showed graphic organizers were an effective way to teach vocabulary (Baumann et al., 2007; Lucas & Goerss, 2007). Finally, the research of Yates, Cuthrell, and

Rose (2011) showed an increase in eighth grade state assessment scores which was attributed to the use of the interactive word walls, but this study did not produce the same results with the post assessment data.

Conclusion

The results of this study are however significant to the field of mathematics literacy and can guide Georgia secondary teachers as they implement the Common Core State Standards (CCSS) (Common Core State Standards Initiative, 2010, the Common Core Georgia Performance Standards (CCGPS) (Georgia Department of Education, 2013), and the Mathematical Practice Standards (Common Core State Standards Initiative, 2015). While the results did not indicate a significant difference between the post assessment scores of the treatment group who used graphic organizers and an interactive word wall to learn mathematical vocabulary and the control group who did not, the ANCOVA results showed a significant relationship between the pre-assessment and the math achievement within groups measured by the post assessment. This finding is promising for secondary math teachers who are considering integrating content literacy and vocabulary study into their math content program of study.

Although the students seemed to benefit from the use of the graphic organizers and an interactive word wall in their use of correct vocabulary, perhaps the time constraint of 6-weeks was too short of a time span to see meaningful results. This study was conducted as the first author's action research project under the guidance of the second author as a requirement for the Education Specialist degree. Both authors acknowledge that vocabulary knowledge is critical to mathematical understanding. Moreover, the Georgia Milestones End-of-Course Test emphasizes reading comprehension, and thus, the importance of vocabulary knowledge to reading comprehension is understood (Georgia Department of Education, 2014a). Vocabulary knowledge has been linked to reading achievement and comprehension (Francis & Simpson, 2003; Pullen, Tuckwiller, Konold, Maynard, & Coyne, 2010; U. S. Department of Education, 2010/2011). Even though a student knows a vocabulary word and can recognize its meaning without the context of the word being understood, content literacy is not achieved. The ability to problem solve according to Sweller (1989) depends on "an extensive, domain-specific knowledge base" (p. 457). Using that vocabulary knowledge to problem-solve leads to mathematical achievement (Baumann et al., 2007; Lucas & Goerss, 2007) and the use of graphic organizers and interactive word walls are a good start.

Limitations

This study was limited by the inability to randomly assign students to the two classes. Another limitation is that the classes were comprised with many underachieving students and with high numbers of special needs students. From this perspective, the results cannot be generalized to gifted or regular education students. More importantly, the study was conducted with one treatment group and one control group in one setting, and these limitations make it difficult to generalize to any population of students. Additionally, the presence of a co-teacher may have influenced the results and the teacher as researcher could have introduced unintentional bias as well. Finally, both groups did learn vocabulary. From this stance, there is a possibility that a sufficient treatment distinction was not made between the treatment and control groups.

Implications

Graphic organizers and interactive word walls are innovative tools to engage students in learning vocabulary, but the results of this study tend to imply that more synthesizing of the word meanings and deeper understandings within the content are required to make a difference in mathematical achievement. While the literature emphasizes that content literacy needs to be infused into content classrooms, the findings of this study tend to suggest that ninth-grade may be a little too late to learn all the necessary vocabulary to be successful in mathematics. Seeing mathematics as a language from the beginning of a student's education would empower students to succeed as they continue through the years of mathematical discoveries.

Recommendations

1. A research study with a much larger sample size and more diverse student population would allow the results to be generalized to a more varied population of students.
2. A research study that takes this study a step further by using writing samples with the vocabulary words in addition to learning the definitions is recommended.
3. Extended time to implement the treatment in this study could allow for a more favorable outcome.

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Appendix A

Constructed Response Scoring Rubric:

Score	*Designation*	*Description*
4	Thoroughly Demonstrated	The student demonstrates a thorough understanding of the standards assessed.
3	Clearly Demonstrated	The student demonstrates a clear understanding of the standards assessed.
2	Basically Demonstrated	The student demonstrates a basic understanding of the standards assessed.
1	Minimally Demonstrated	The student demonstrates a minimal understanding of the standards assessed.
0	Incorrect or Irrelevant	The response is incorrect or irrelevant.

Appendix B

Vocabulary Words

curve
function
linear equation
relation
natural numbers
continuous
intercept
natural numbers
rate of change
real numbers
slope
whole numbers
exponential function
factor
explicit equation
variable
vertical shift
constant ratio
dependent variable
function notation
ordered pair
solution set
sequence
extrema
interval 4
negative function
ratio
relative maximum
slope-intercept
x-intercept
linear function
growth factor
exponential equation
transformation
arithmetic sequence
geometric sequence
domain
independent variable
range
discrete
asymptote
integer
irrational numbers
positive function
rational number
relative minimum
undefined slope
end behavior
y-intercept
equation
expression
translation
common difference
parameter