ABSTRACT

The Effects of a Computerized Study Program on the Acquisition of Science Vocabulary

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The following study examined the difference in science vocabulary acquisition comparing computer-assisted learning and a traditional study review sheet. Fourth and fifth grade students from a suburban school in central Texas were randomly selected and randomly assigned to either experimental group or control group. Both groups were given a pre-test to measure prior science vocabulary knowledge and to measure differences within the groups. Both groups learned 24 science vocabulary words over a two-week period. Both groups had the opportunity to study for five days. The experimental group studied using Study Hall 101 (Raley, 1999/2006), an interactive computer game designed to increase learning of vocabulary. The control group studied the vocabulary words using a paper review sheet. At the end of the two-week intervention, both groups took an immediate post-test assessing science vocabulary learned. Another test was given two weeks later to assess retention of the words. A mixed repeated measures 2 X 3 ANOVA was used to analyze the interactions. A repeated measures was used to analyze which group improved. Independent t-tests were

used to analyze the differences between experimental and control groups. Analysis showed that although the groups had similar pre-intervention scores, the students' scores were significantly different at post and delayed post-tests. Students who studied science vocabulary words using Study Hall 101 (Raley, 1999/2006) showed a significant statistical difference in the amount of science vocabulary words they learned *and* retained as compared to the review sheet group. In addition, effect sizes indicated large and moderate strengths for science vocabulary words learned ($d = 0.76$) and for words retained ($d = 0.58$) when using Study Hall 101 (Raley, 1999/2006).

The Effects of a Computerized Study Program on the Acquisition of Science Vocabulary

by

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CHAPTER ONE

Universally, science knowledge is considered a key component in individual as well as community, national, and global success. Individuals who value science not only tend to use scientific knowledge to understand the world in which they live, but also tend to integrate that knowledge in order to problem-solve (Post, Rannikmae, & Holbrook, 2011) and examine relationships and universal laws. This integration allows them to engage in critical thinking (Bybee & Fuchs, 2006) and related tasks. Specifically, with fast-paced changes and demands in today's society, educational reform for the 21st century demands success in science for all students so that they can be competitive and successful (Bybee & Fuchs, 2006; National Assessment Governing Board, 2011).

At the individual level, science literacy improves student knowledge in science as well as other areas such as math and reading (Upadhyay & DeFranco, 2008). Science literacy also positively impacts life. "It is associated with the capability to transfer knowledge, skills, attitudes and values to unknown situations such as showing initiative, thinking critically or reasoning oneself in a collaborative working situation" (Post et al., 2011, p. 204). Individuals who see scientific knowledge as an important part of the world are also more inclined to see the field of science as necessary and to even consider it as a life profession.

Scientific literacy at the societal level is "valued in a competency-based society where scientific excellence and technological innovation is the key to success" (Post et al., 2011, p. 205). Growth and competitiveness in the U.S. economy rely on an adequate source of competent individuals entering the STEM fields of science, technology, engineering, and mathematics (Lee, 2011). Stakeholders, those experts in the field who view the trends and direction of society and provide employment to the future workforce, expect their employees to have a scientific literacy and knowledge base higher than ever before (Post et al., 2011).

Students who are not successful in the content areas where there is increased demand can experience a “loss of future opportunities in society” (Mastropieri et al., 2006, p. 130). Unless the U.S. keeps up with this demand, it is in danger of losing its edge in today’s global, competitive economy. A workforce that brings higher levels of science skills and understanding is needed. Science education must be viewed as an essential part of building a stronger workforce adept at scientific literacy (Bybee & Fuchs, 2006). Because STEM workers who play a critical role in boosting the economy are in high demand, improving equal educational opportunities in the STEM learning processes will, potentially, enhance the productivity of the national economy (Lee, 2011).

Limited Student Knowledge and Skills in Science

Although the importance of science literacy for success is clear, data suggest students are having difficulties attaining science knowledge (National Assessment Governing Board, 2011). A current look at fourth, eighth and 12th grade students in science across the nation, gathered by The National Assessment of Educational Progress (NAEP) and disseminated in A Nation’s Report Card (National Center for Education Statistics, 2011), provides a disheartening picture of the lack of science knowledge at each grade level. The NAEP results indicated that 72% of fourth graders, 63% of 8th graders, and 60% of 12th graders performed at or above the *Basic* level indicating only partial mastery of fundamental knowledge and skills needed to show proficient work in science. Only 34% of fourth graders, 30% of eighth graders, and 21% of 12th graders performed at or above the *Proficient* level indicating competency over challenging science material. An even smaller percentage of students showed superior performance indicated by the *Advanced* level. One percent of fourth graders, 2% of eighth graders, and 1% of 12th graders performed at this level.

National education policy requires that students meet high standards in science (August, Branum-Martin, Cardenas-Hagan, & Francis, 2009). Due to the difficulties students are having attaining science knowledge, it is critical that students "be provided with the appropriate skills and knowledge for achieving higher levels of scientific and technological literacy" (Post et al., 2011, p. 203). Clearly, there is a need for research to continue to identify effective and practical methods of instruction (Fontana, Scruggs, & Mastropieri, 2007) in order that teachers can develop students' knowledge and skills in science. It is our obligation as a nation to provide a strong foundation to young people in the field of science so that they may be informed as well as have opportunities to pursue science as a career (National Assessment Governing Board, 2011).

Importance of Vocabulary in Developing Students' Knowledge and Skills in Science

Overall, vocabulary knowledge is a crucial component of success in school (Blachowicz & Fisher, 2008; Coyne, Simmons, Kame'enui, & Stoolmiller, 2004; Templeton, Bear, Invernizzi, & Johnston, 2010). However, "vocabulary development, although clearly recognized, has not received the same degree of instructional attention as other literacy skills" (Baker, Simmons, & Kameenui, 1995, p. 1). Strong vocabulary skills provide many advantages to learners. Vocabulary is an essential component of background knowledge which is imperative for understanding (Marzano & Pickering, 2005). Comprehension can be improved if meaning access becomes automated. Rather than focusing on the meaning of words, the learner's attention can be focused on passage comprehension (Mayer, 2008). In addition, the more a person understands terms, the easier it is to understand what is read (Marzano & Pickering, 2005). In order to ensure understanding of words that are not part of a student's everyday experiences, certain vocabulary words should be taught directly (Sousa, 2011). "Vocabulary differences between students are extensive. Differences arise early, and the vocabulary gap between students grows larger over time" (Baker et al., 1995, p. 1).

Academic-Specific Vocabulary

Specifically, the language of a discipline is particularly important. Vocabulary plays an important role in the understanding of subject-specific matter. This core academic vocabulary, although not language that is spoken every day, is important to understanding, reading and writing in academic fields of study (Templeton et al., 2010). "An increasingly large percentage of the approximately 3,000 words students learn per year in the early primary grades are more complex, infrequently used words, reserved primarily for specialized academic activities" (Baker et al., 1995, p. 4).

Academic vocabulary development is especially important because content-specific text books tend to have challenging vocabulary (Dimino, 2007). As compared to general vocabulary, content-specific vocabulary can be harder to learn because of new concepts that are presented (Templeton et al., 2010). Learning of domain-specific vocabulary helps students become familiar with the language of a subject and to develop a level of expertise within the subject matter (Bryant, Ugel, Thompson, & Hamff, 1999).

While most teachers teach the language of the particular discipline (Templeton et al., 2010), methods of teaching vocabulary may not always be equal. Teaching specific academic terms using systemic direct instruction is one of the strongest actions a teacher can do to ensure understanding of academic content (Marzano & Pickering, 2005; Mayer, 2008). Without specific instruction in vocabulary development, students often have the conceptual meaning but don't have the "label" (Templeton et al., 2010, p. 5). "Students also may reduce the extent to which they investigate word meanings independently if they begin to view the vocabulary demands as too difficult" (Baker et al., 1995, p. 13).

Science Vocabulary

Specifically, the knowledge of science vocabulary plays a pivotal role in the understanding of over-arching concepts as well as specific science information. "Without a clear understanding of the language of science, students are likely to have difficulty with science content" (Shook, Hazelkorn, & Lozano, 2011, p. 45). Much of the content in the science classroom requires vocabulary "restricted to subject-specific discussions" (Baker et al., 1995, p. 11). The ability to synthesize previous knowledge with new knowledge, and the ability to apply it to higher order thinking also requires knowledge of subject-specific vocabulary.

Science, in particular, demonstrates a learning progression--in order to progress to more sophisticated skills and understanding, there must be a novice level of understanding of the subject facts and skills (National Assessment Governing Board, 2011). In order for students to obtain "Full Concept Knowledge" of a word, they must first have a "Verbal Association" for that word (Baker et al. 1995, p. 3). Instructional strategies such as learning definitions and utilizing computer-assisted learning can facilitate this necessary knowledge base. If the ratio of unknown to known science vocabulary words is too great, comprehension may be negatively impacted and students may not be able to deepen their understanding (Nagy, Anderson, & Herman, 1987). Students who understand more words through vocabulary instruction have more opportunities to increase higher order skills by making meaningful inferences (Mayer, 2008).

A review of the literature by Mastropieri et al. (2006) reports that one reason some students specifically have a difficult time in science is because of the difficulty of acquiring science vocabulary. Many times teachers ask themselves, "How do I get my students to understand the concepts when they don't even understand the basic vocabulary?" (Shook et al., 2011, p. 45).

Methods Used in Teaching Academic-Specific Vocabulary

Marzano and Pickering (2005) claim there is a "strong argument for teaching academic terms" for success (p. 2). They reported on a research study that indicated an increase in comprehension from the 50th percentile to the 83rd percentile (effect size 0.97), after specific-content terms were taught. Surprisingly, however, a review of the literature did not reveal many studies on learning strategies for general vocabulary or specifically, for science vocabulary. There is little in the field that explores whether enhancements can improve traditional methods in vocabulary acquisition (August et al., 2009).

A majority of the searches on vocabulary acquisition provided information dealing with metacognition, self-efficacy, and/or the importance of learning vocabulary rather than studies on specific instructional strategies for learning vocabulary. A few studies that were found that did address specific instructional strategies for vocabulary are discussed in this section.

Non-Science Vocabulary

The studies dealing with learning non-science academic vocabulary terms that were found included the use of flashcards, practice, and direct instruction. For example, Steele (2007) suggested the use of flashcards as a useful study strategy. Mastropieri and Scruggs (2007) found practice as one of the key elements in strategies for improving memory and D'Alesio, Scalia, and Zabel (2007) reported that direct instruction, along with other strategies, improved vocabulary acquisition.

Science Vocabulary

One study focused on science vocabulary that used participants who were not specifically identified as having learning disabilities. This study reported positive gains. August et al. (2009) conducted a cluster-randomized study involving 20-6th grade classrooms designed to increase acquired science knowledge and literacy skills. The study used several components in order to increase vocabulary knowledge, but emphasis was placed on direct instruction of science-specific vocabulary. After nine weeks of intervention, positive gains were seen, on average, in performance for science vocabulary outcomes. Effect size was in the moderate range (0.28 to 0.37). While the authors examined short-term gains, they did not look at long-term retention of the vocabulary words.

Vocabulary Studies using Technology-Driven Instruction

Some authors suggest the potential for enhancing vocabulary using computerized methods (Fuchs et al., 2006). MacArthur, Haynes, Malouf, Harris, and Owings (1990) compared the use of computers with paper and pencil techniques in the learning of spelling words. This study reported differences in favor of the computer-assisted instruction (CAI) condition on weekly spelling tests and on a retention test presented at a later time. Johnson, Gersten, and Carnine (1987) used CAI to compare how the size of a vocabulary set to be learned and how the amount of review time incorporated would impact vocabulary acquisition. They found that although all of the students in the study performed similarly in the amount and accuracy of words learned, the students with the smaller word set were able to learn the words in a shorter amount of time than the students learning vocabulary with a larger word set. Breaking the words down into smaller sections improved acquisition time. Moreover, Lin, Chan, and Hsiao (2011) examined how collaboration and technology together would impact vocabulary acquisition and long-term retention. Of three different groups − learning individually without computers, learning collaboratively without computers, and learning collaboratively with computers, the collaborative group learning with technology were able to remember more of the vocabulary after a one-month delayed post-test. However, none of these studies examined the effects of CAI on the acquisition of science vocabulary.

Learning Theory Related to Knowledge Acquisition

Effective strategies in learning vocabulary are built on a variety of principles that are based primarily in learning theory. The theoretical foundation of instructional design whose principles are based in behaviorism, however, provides the basis for understanding more about knowledge acquisition and retention. Instructional design based in behaviorism is especially applicable to the learning of academic-specific vocabulary.

Direct Instruction Model

Direct instruction, based on the theory of behaviorism, has evolved through time in response to what has been acquired about learners and knowledge acquisition. It remains an approach that has proven to be useful and effective (Al-Shammari, Al-Sharoufi, & Yawkey, 2008; Flores & Kaylor, 2007; Gujjar, 2007; Magliaro, Lockee, & Burton, 2005).

Behaviorists suggest, “infants are born with capacities to discriminate aspects of the environment, respond to it, generalize, and so on” (Strauss, 1993, p. 193). Behaviorism stresses that a new behavior occurs when it has been automatic through repetition (Ang, Avni, & Zaphiris, 2008). This is known as knowledge acquisition or learning. Facilitation of the learning process through direct instruction enhances the student’s ability to learn key information. The goal of this particular model is that learners will obtain mastery through automaticity of skills leading to specific knowledge (Magliaro et al., 2005).

Reinforcement

Learning occurs when a response from the environment brings about a change in behavior (Ormrod, 2008). Behavior is molded by “unpleasant and pleasant consequences” (Ang et al., 2008, p. 537). Skinner formulated a concept within behavioral theory that addressed these reinforcers (Hergenhahn, 1982). Known as operant conditioning, it proposed two general principles: "(1) any response that is followed by a reinforcing stimulus (reward) tends to be repeated; and, (2) a reinforcing stimulus (reward) is anything that increases the rate with which an operant response occurs" (Hergenhahn, 1982, p. 86). Ormrod (2008) paraphrases it this way: "A response that is followed by a reinforcer is strengthened and is therefore more likely to occur again" (p. 51). Reinforcement increases the chance that the behavior will be repeated and strengthened (Joyce & Weil, 1996). Skinner, however, was careful to use the word reinforcer rather than reward (Ormjrod, 2008). While the word reward has the connotation of "pleasant and desirable," reinforcers can bring about change regardless of the emotion attached to the reinforce (Ormrod, 2008, p. 52). A reinforcer is defined by its effect on behavior.

> Essentially, a stimulus evokes a behavior (response), which generates consequences, which, if reinforcing, strengthen the likelihood that a similar stimulus will elicit the behavior that was reinforced. Reciprocally, negative consequences will make it less likely that the behavior will be elicited. (Joyce & Weil, 1996, p. 323)

The task of the educator, then, is to take this knowledge of reinforcement and translate it into instructional material that will increase learning and avoid variables that discourage learning (Joyce & Weil, 1996).

Mastery Learning

Based on John Carroll's perspective of aptitude, mastery is the amount of time that it takes a student to learn something "rather than his or her capacity to master it (Joyce & Weil, 1996, p. 329). Joyce and Weil (1996) wrote that Benjamin Bloom believed that if instruction is structured in such a way as this, then "time to learn can be adjusted to fit aptitude. Students of lesser aptitude can be given more time and more feedback" (p. 330).

"Inherent in the behaviorist perspective is the belief that, given appropriate environmental conditions, people are capable of acquiring many complex behaviors" (Ormrod, 2008, p. 111). Behaviorists believe that in order for this learning to occur, a student must master the content of one lesson before progressing on to the next. Therefore, learners "should be taught difficult concepts after they have been first exposed to the simple ones" (Ang et al., 2008, p. 537). Learning can occur if approached correctly. The premise of mastery learning, then, is that given enough time and the appropriate instruction, "most students can learn school subject matter" (Ormrod, 2008, 112).

Mastery learning, which focuses on the learning of specific information, usually includes the following components: (a) defined objectives for learning are specified; (b) material is broken down into small units; (c) lessons based on smaller units are presented in a logical sequence for mastery; (d) opportunities for practice are provided with mastery of each small lesson being the goal; (e) feedback is immediate; (f) mastery is demonstrated before moving on; and, (g) data were used to decide whether additional help or practice is needed if students do not show mastery (Magliaro et al. 2005; Ormrod, 2008; Wambugu & Changeiywu, 2007).

Technology-Driven Instruction

Understanding the tenets of the direct instruction model, it is easy to see how technology-driven instruction can work especially well when learning targeted information such as academic-specific vocabulary. At times, technology-driven instruction can be more advantageous than traditional teacher generated direct instruction. Ormrod (2008) writes that computer-assisted instruction (CAI) has several advantages. First, the computer program can proceed from lesson to lesson as needed without teacher input. Second, CAI can present information to be learned in ways that traditional teaching cannot such as the ability to use moving graphics and sounds. Third, the computer can record and store on-going data for each individual student. This information might include things such as how often the student is right or wrong, how quickly the student responds, etc. This allows the teacher to monitor student progress and decide which student needs additional practice. And, finally, the computer can provide instruction without a teacher being involved in the process. This allows educators efficiency (Carnine, 1989), flexibility in instruction, and possible savings of monetary resources.

Vocabulary instruction can benefit from technology-driven instruction. "The research support is clear that to incorporate new words into the receptive or expressive lexicons, students need multiple exposures to words" (Baker et al., 1995, p. 7) and technology-driven instruction can provide as many exposures as needed. Better learning is often achieved through computer-assisted instruction and mastery learning (Ormrod, 2008). Specifically, Dani and Koenig (2008) advocate learning science content through technology-driven instruction.

Gaps in the Literature

Research exploring research-based methods proven to increase student mastery of science skills is scarce (Bybee & Fuchs, 2006). While some studies used components of direct instruction and practice, none incorporated the two together in the learning of science vocabulary. Furthermore, none promoted studying science vocabulary with the use of technology-driven instruction.

Problem

Because of the lack of research in the literature which looks specifically at strategies to study science vocabulary, and because technology-driven instruction provides an advantageous method to learning academic content, this study examined how studying science words using a computerized study program compared to studying science words using a traditional vocabulary review sheet that provided key science vocabulary words and the definitions for each. Specifically this study examined the following questions:

1. Is there a difference in the growth of science vocabulary between students who participate in a computerized vocabulary program versus those who participate in a traditional vocabulary review sheet?
2. Is there a difference in science vocabulary retention between students who participate in a computerized vocabulary program versus those who participate in a traditional vocabulary review sheet?

CHAPTER TWO

Scientific knowledge plays a critical role in the success of our global and local communities in the 21st century (Sjøberg, 2001). While scientists and researchers place emphasis on scientific literacy, the scientific method and the knowledge that comes from further exploration requires each individual to have background knowledge of science language and concepts (President's Council of Advisors on Science and Technology, 2010). An underlying base to this background knowledge is understanding the vocabulary of science−the language of the discipline. A solid foundation in the language of science, including specific science vocabulary, leads to deeper and more complex understanding. In order for science as a discipline to move forward and toward possible paradigm shifts, which allow change and growth to occur in a discipline, this language of the discipline must be understood and available for discussion (Kuhn, 1962).

In this chapter I discuss the importance of science vocabulary and why it is necessary to explore a strategy that might increase science vocabulary knowledge for intermediate school students. I first discuss the importance of the science, technology, engineering, and mathematics (e.g., STEM) disciplines and the need for all citizens to have a solid foundation in science. I next explore the difficulties that students encounter acquiring science knowledge. Next I examine the research about vocabulary acquisition and the relationship that it shares with science vocabulary and increased knowledge. Then I summarize research studies that examine strategies attempting to increase science vocabulary knowledge as well as vocabulary knowledge in other core disciplines.

Finally, I examine the foundation learning theory on which this study is based and present a rationale for this study, exploring a technology-based strategy that can be used to possibly increase science vocabulary knowledge.

Importance of Science in Today's Society

Research makes it clear that science knowledge is important to the individual as well as to the nation and world as a whole (Committee on Science, Engineering, and Public Policy, 2007; Sjøberg, 2001). Without understanding specific vocabulary used in science, students cannot achieve the level of science knowledge that is needed today both nationally and globally.

As people move forward as a technological society, it becomes more evident that knowledge in the STEM fields is needed if not essential. Areas that benefit from strong STEM fields include industry, universities and research institutions, schools, the labor market, and citizens involved in democratic participation (Sjøberg, 2001). This need for scientific literacy exists regardless of cultural differences (Graber et al., 2002), gender (Sjøberg, 2001), race (President's Council of Advisors on Science and Technology, 2010), or disability classification (Lee, 2011). Educators need to provide equal opportunities for a strong science foundation. Historically, beginning with the launching of Sputnik, which fostered the urgent need to "undertake the most dramatic educational reforms of the 20th century" in order to compete with the Soviet Union (Committee on Science, Engineering, and Public Policy, 2007, p. 303), the U.S. has pushed for increased education and funding in the areas of STEM. However, through the years, less emphasis and less monetary resources have been funneled into these areas (Committee on Science, Engineering, and Public Policy, 2008). Furthermore, there is doubt about continuation of such funding (Committee on Science, Engineering, and Public Policy, 2007). In comparison, many countries around the globe are now focusing on research as a top priority. Many nations are investing aggressively in higher education, increasing public monies into the sciences, and publishing more in research journals than the U.S. (Committee on Science, Engineering, and Public Policy, 2007). The U.S. has begun to see a decline in tests scores in science and math (National Center for Education Statistics, 2011). In addition, fewer and fewer students are choosing to go into the sciences (Sjøberg, 2001). Overall, the United States has not kept up with others nationally and is falling behind in the STEM disciplines (President's Council of Advisors on Science and Technology, 2010; Thompson & Bolin, 2011). It is important, then, to reposition the national focus on fostering interest in these subject areas (Gattie & Wicklein, 2007) and teaching students using best practices in the classroom to influence success (Whitehouse, 2011).

Currently, many factors lend hope to a resurgence of knowledge and competitiveness in STEM areas. History has shown that in times of economic downturn, it is not uncommon to see a push in an increase of demand in areas of STEM. This increased demand provides incentives for more individuals to focus on STEM disciplines and seek additional schooling and jobs (Williams, 2011). Government agencies are also showing interest in increasing the number of STEM workers in the U.S. by working collectively to gain better training for students and increased job opportunities. In July 2011, President Obama launched the *Educate to Innovate* campaign which is designed to increase the participation and improve the performance of America's students in STEM areas: science, technology, engineering, and mathematics. It also includes efforts from the federal government and from “leading companies, foundations, non-profits, and science and engineering societies to work with young people across America to excel in science and math” (Whitehouse, 2012, para. 1). This effort involves public and private investments of over $260 million to help American students compete and move forward. Additionally, in 2012 the White House announced the second year of the National STEM Video Game Challenge‒a competition to encourage creativity in creating video games to encourage motivation for STEM disciplines (Whitehouse, 2011). Local and state entities are also pushing to increase foundational knowledge and encourage more students to enter the STEM disciplines. For example, the University of Georgia is proposing a way to increase student interest and improve skills in math and science by proposing a change in their technology education. The goal is to use an engineering design within their technology education to give students the opportunity to see the usefulness of math and science and apply it to their lives using technology (Gattie & Wicklein, 2007). With this new focus the university hopes to open the door to more students interested in the engineering field.

The role of science and technology is more crucial than ever for success in the 21st century. President Barack Obama acknowledged the importance of science knowledge in today’s world: “Reaffirming and strengthening America’s role as the world’s engine of scientific discovery and technological innovation is essential to meeting the challenges of this century” (Obama, 2009, para. 3). It is apparent that STEM reform is a high priority in education today and educators are focused on looking for ways to improve their students’ science knowledge and achievement (Dynamic Literacy, 2007). Whether the U.S. remains a leader throughout the nations and whether the U.S.

will be able to compete in challenging areas such as energy, health, environmental protection, and national security depends on the success of STEM education (President's Council of Advisors on Science and Technology, 2010). Increasing knowledge and success in the sciences is critical for the nation.

Limited Student Success in Science

It is obvious that science plays an important role in the world today and that citizens who are literate in scientific concepts are needed (Graber et al., 2002; President's Council of Advisors on Science and Technology, 2010). However, "in general, many Americans do not know enough about science, technology, and mathematics to contribute to or benefit from the knowledge-based society that is taking shape around us" (Committee on Science, Engineering, and Public Policy, 2007, p. 314).

In addition, students are not performing well in the sciences. This is a major concern and appears to be the case in grades K-12. When comparing U.S. students with their peers across the globe, U.S. students do worse on average in math and science the longer they are in school (Committee on Science, Engineering, and Public Policy, 2007, p. 303). For instance, Mamlok-Naaman (2011) concluded that many 10th grade students are unfamiliar with basic concepts appearing in the science curriculum (i.e., hypothesis, isotopes) despite the fact that these students studied these science terms in junior high school. In relation to other more familiar concepts (i.e., atom, element, energy), which students indicated that they had knowledge of the meanings of the words, not all of the students were willing to explain these words. Even though students had multiple exposures to these science vocabulary words in subsequent years, it appeared that students still did not display an understanding of these basic science concepts.

Even at the post-secondary level, though students choosing STEM majors are increasing, the U.S. is not seeing graduation rates that indicate success (Thompson & Bolin, 2011). Currently, approximately 300,000 students graduate with STEM bachelor degrees and associate degrees in the U.S. annually. But, of those students entering college who intend to major in a STEM discipline, less than 40% actually complete a STEM degree (President's Council of Advisors on Science and Technology, 2012). As a nation we must focus on preparing all students, including those that are currently underrepresented, to be proficient in STEM disciplines "to meet our needs for a STEM-capable citizenry, a STEM-proficient workforce, and future STEM experts" (President's Council of Advisors on Science and Technology, 2010, p. 6).

Importance of General Vocabulary Development and Science

Vocabulary Development

Understanding the language of a discipline is critical in facilitating the learning process. Retention of this knowledge can be increased by using effective strategies for vocabulary acquisition such as direct instruction and practice (Pany, Jenkins, & Schreck, 1982). Knowledge and literacy play an important role within the sciences. However, evidence suggests that students are not retaining science knowledge. The performance of students in the U.S. in science achievement is low compared to other developed nations (Carnine & Carnine, 2004). This lack of knowledge is impacting not only students' success in school, but also their ability to graduate in STEM disciplines. This, in turn, impacts students' ability to obtain STEM jobs that are important to our economy and success with today's technological focus. Although many factors influence success in the sciences, vocabulary knowledge is key in promoting understanding of science concepts. Professionals agree about the importance of developing vocabulary (Pany et al., 1982). However, learning the meaning of words presents the biggest challenge to understanding, even more so than length of words and frequency (Nagy et al., 1987). By providing students strategies to learn science vocabulary, it "can significantly support their understanding of and interest in the language of science" (Shook et al., 2011, p. 45).

Effects of Learning General Vocabulary

In order to discuss the merits of vocabulary, it is important to first understand what is meant by the word vocabulary and why it is important. Merriam-Webster (n.d.) defines vocabulary as "a sum or stock of words employed by a language, group, individual, or work or in a field of knowledge." Schatschneider, Harrell, and Buck (2007) define vocabulary as "the ability to understand the meanings of words" (p. 252). Culturally, vocabulary development is important for knowledge building (Pressley, Disney, & Anderson. 2007) and communication, but also because language abilities affect academic success (McGuinness, 2005). Nagy et al. (1987) found that one of the greatest influences impacting learning from context was the amount of unfamiliar words to the reader that were difficult conceptually. In fact, they reported that there was no learning by context at all with the most conceptually difficult words. A study by Pany et al. (1982) also indicated that sentences containing words learned through context produced lower comprehension. And, more importantly, when students were effectively taught vocabulary words using direct instruction, these strategies also produced transfer of vocabulary knowledge to sentence comprehension.

The benefits of vocabulary knowledge are many. First and foremost, vocabulary knowledge impacts understanding at the most basic level. "People's knowledge of any topic is encapsulated in the terms they know that are relevant to the topic" (Marzano & Pickering, 2005, p. 2). Vocabulary is also a critical component in becoming a proficient reader (Bravo, Hiebert, & Pearson, 2007). Most researchers in reading assume the vocabulary-reading link (Constantinescu, 2007; McGuinness, 2005; Pany et al., 1982). Students must understand the vocabulary of the discipline in order to read a text. "There is some indication that reading comprehension is more strongly linked to vocabulary than to simple decoding, and that this connection is stronger in older children" (McGuinness, 2005, p. 271). A study by Nelson and Stage (2007) showed significant gains, both statistically and educationally, in both vocabulary knowledge and reading comprehension when vocabulary instruction was imbedded into the traditional language arts instruction compared with standard instruction. These gains were seen most in reading comprehension. In addition, reading to learn, also known as content area literacy, can occur when students are able to comprehend the language of the discipline used to deliver specific content (Dynamic Literacy, 2007). Moreover, students learn additional words of the discipline by reading and understanding the text (Bravo et al., 2007).

Vocabulary provides important background knowledge that facilitates increased understanding. In order to understand complex texts within a particular discipline, students must develop specific background domain knowledge (Moje, 2008). The ability to integrate new information with this prior knowledge plays an important role in understanding (Nagy et al., 1987). The more understanding a student has within a domain, the more that student will be able to connect new words and knowledge and thus increase further understanding (de Villiers & Johnson, 2007). A study by Shook et al. (2011) showed that an increase in vocabulary knowledge increased the knowledge of content. In addition, students who understand the concepts of a particular discipline feel more confident in their knowledge, which leads to increased motivation and improved achievement (Mamlok-Naaman, 2011).

Uniqueness of Science Vocabulary

Vocabulary significantly supports understanding of a discipline (Dynamic Literacy, 2007). Specifically, science vocabulary development is critical to understanding science concepts and boosting learning (Pressley et al., 2007). "As a content area, science is unforgiving in terms of the constant need to build knowledge and the terminology needed to express that knowledge" (Bravo et al., 2007, p. 142). While many every day words can have synonyms that convey a similar meaning, science words have a precise definition in order for students to understand science texts or discussions involving science concepts (Bravo et al., 2007). Students can easily gain an understanding of words that are used on a more personal, every day basis. However, when it comes to science, there are times that students must learn a new definition of the same word in order to create a solid foundation. Furthermore, to be able to learn science concepts by reading independently, students must be able to understand approximately 90% of written text (Dynamic Literacy, 2007). If students are not able to learn the meaning of science vocabulary words through independent reading as well as discussion, then understanding and long-term memory may not occur.

There are many reasons why a strong vocabulary is crucial for being successful in science. First, science is composed of many concepts that are unfamiliar to students

(Sjøberg, 2001). Science texts tend to deal with information that students may have been exposed to but "have never consciously analyzed or addressed" (Bravo et al. 2007, p. 143). Therefore, many times the definitions of science vocabulary are wrongly assumed (Hiebert & Cervetti, 2011). It can be difficult to learn science information unless students learn vocabulary associated with these concepts.

Second, science texts can be difficult to understand. There are many criticisms of science textbooks (Carnine & Carnine, 2004). Science words are long and conceptually complex (Hiebert & Cervetti, 2011). Reading science texts requires much more than just pronouncing words. Understanding the language of science "requires understanding a complex, conceptual construct" (Bravo et al., 2007, p. 143). In addition, complex phrases are often used in science texts. Although students may understand the meanings of individual words within phrases, the meaning of the phrase often has its own unique meaning. These complex phrases create difficulties for students when reading science (Hiebert & Cervetti, 2011). Science texts typically introduce unfamiliar vocabulary. These words tend to come in groups and form semantic networks with other groups of words (Bravo et al., 2007; Marzano & Pickering, 2005). Without a solid understanding of the language that forms these networks it can be difficult to understand the new concepts or link those concepts to prior knowledge. Disciplinary texts can be extremely challenging to the reader with little prior knowledge of the discipline (Moje, 2008). A good predictor of students' ability to understand science textbooks is their level of science vocabulary knowledge (Young, 2005).

In addition, science texts use expository text to teach concepts. Expository text tends to be more difficult than narrative text. When reading narrative text, a student may ascertain the meanings of unknown words by use of context clues with which the student is familiar. However, context does not always give enough information to help the reader. For example, Nagy et al. (1987) were surprised to find that no learning of new vocabulary words occurred while using context for the most conceptually difficult words. In science texts, there are usually no clues to help figure out the meaning of technical terms (Bravo et al., 2007; Pressley et al., 2007).

Furthermore, the vocabulary found in science texts differs dramatically from vocabulary found in narratives, which calls for a different kind of focus (Bravo et al., 2007). In an analysis done on narrative vocabulary and science vocabulary, Hiebert and Cervetti (2011) concluded,

> the words in the narrative vocabulary are more likely to be familiar to students than the words in the science corpus but are predicted to appear less frequently. Although they are less familiar but more frequent, the science words are significantly longer and have definitions that are more conceptually complex. (p. 9)

Developing students' abilities to understand complex science textbooks creates considerable cognitive and pedagogical issues (Prain & Waldrip, 2010).

Third, science vocabulary tends to be difficult because of lack of exposure. Hiebert and Cervetti (2011) explain that when examining the frequency of words in the English language, words can be divided into three categories: high, moderate, and rare. Words found in the rare category are typically unique to specific domains such as the word *thermal*. With such little exposure it is difficult to learn the meaning of a word without direct instruction of that word. Nagy et al. (1987) agree: "Teachers cannot rely on a single reading of an expository passage to communicate new conceptual domains to their students" (p. 266). It is also difficult for students to incidentally learn the meaning of academic science terms in everyday language because there is not a venue for hearing or using the words outside of the school setting (Bravo et al., 2007). Even with exposure to science words that describe scientific concepts, Mamlok-Naaman (2011) reported most students did not feel they were adequately familiar with the words.

Fourth, "self-efficacy contributes to the acquisition of knowledge and the development of skills," (Tsai, Ho, Liang & Lin, 2011, p. 759). When students attempt to learn information that is unfamiliar or novel, they tend to have lowered self-efficacy for that information. As students become more familiar with information they tend to experience higher self-efficacy. Thus, the more students are exposed to subjects in the spheres of science and technology, the more they will become interested and involved. And, those who are interested in science and understand the scientific concepts have better attitudes towards science and science studies than those who have learning difficulties in the science disciplines (Mamlok-Naaman, 2011).

Overall, because science vocabulary knowledge plays such a pivotal role in understanding wider scientific concepts it is important to clarify those as much as possible (Mamlok-Naaman, 2011). In order to increase science vocabulary knowledge, educators must develop specific instructional strategies for academic-specific informational words (Hiebert & Cervetti, 2011; Marzano & Pickering, 2005).

Methods of Vocabulary Instruction

There have been few studies looking specifically at the acquisition of vocabulary knowledge (Pany et al., 1982). However, vocabulary learning is beginning to find a place in reading instruction discussions and research after many years of taking a backseat to other reading interventions. The importance of vocabulary has been highlighted in policy statements and among researchers. Findings about vocabulary in the report of the National Reading Panel Policies have influenced the policies and practices in No Child Left Behind Act (Pearson, Hiebert, & Kamil, 2007), which in turn have impacted curriculum and intervention. There is also agreement among professionals about the importance of vocabulary development for success (Pany et al., 1982). "There is a reciprocal relationship between vocabulary acquisition and reading comprehension. The better the students' vocabulary knowledge is, the better they perform with reading comprehension tasks" (Constantinescu, 2007, para. 23).

Because there is increased understanding that vocabulary plays an important role in reading comprehension (Horn & Feng, 2012), academic-specific core subjects (Carter & Dean, 2006; Holmes, Holmes, & Watts, 2012), and academics in general (D'Alesio et al., 2007), "there is good reason to teach vocabulary more aggressively" (Pearson et al., 2007, p. 282). In fact, as children get older, it is vocabulary that limits reading much of the time, not decoding. However, current studies suggest that education is doing little to encourage vocabulary instruction (Biemiller, 2004), and there are gaps in studies that do explore vocabulary acquisition (Fazeli, 2012).

Studies Examining Vocabulary Acquisition

General Vocabulary Acquisition

While the importance of vocabulary has been established, no one intervention has emerged among researchers. Strategies such as explicit direct instruction, use of context clues, and incorporating technology have all been explored in teaching general vocabulary. This section describes the research support for these strategies.

Use of Direct Instruction

Several studies have examined the effectiveness of using direct instruction as one of the methods of increasing vocabulary knowledge. Dietrich (2008) examined whether there was a difference between students' vocabulary knowledge gained when an explicit vocabulary program was implemented. Students (N = 25) were divided into an experimental and control group. Both groups had a similar distribution of ELL's and non-ELL's. The experimental group received explicit direct instruction of vocabulary words through teacher directed lessons. This explicit vocabulary training included many components including multiple exposures and review. Each lesson contained a read-aloud story. Over three days meanings of words were reinforced through photo cards and workbook activities. The researcher reported that these opportunities allowed students to talk about the words being taught in their own words and using their own experiences. The control group did not receive direct instruction of the vocabulary words. They participated in the school's normal read-aloud initiative that introduces words through weekly video-taped stories. Before the intervention a pre-test was administered to measure vocabulary knowledge of the two groups. Analysis on the pre-test found no statistical difference between groups. However, after a 12-week intervention, results indicated a significant difference in the scores between the control group and experimental group in vocabulary and listening comprehension.

Pany et al. (1982) investigated how varied levels of direct instruction would increase vocabulary acquisition as well as improvement in passage comprehension. Researchers conducted three different studies to examine the effects of direct instruction. The first two studies (N = 12 and N = 6, respectively) looked at students without and with learning disabilities. All students received each of the treatments and served as their own control. Treatment instruction occurred over three days. Students were divided into pairs and taught 24 vocabulary words with varying levels of direct instruction. The amount of direct instruction increased based on the following levels: No-Meanings (control) − students read individual target words on index cards; Meanings from Context − no direct instruction was given − students read one sentence with the target word and one sentence with a synonym of the target word; Meanings Given − students read a target word and then the researcher provided the meaning of the word and a sentence containing the word using every day language; and Meanings Practiced − students read target word and the researcher provided a synonym and a sample sentence − the student then repeated the target word and the synonym. Additional words were added to the target words in order to increase the difficulty of the task. When all target words were presented, the student attempted to state the correct meaning and corrective feedback was given when needed by the experimenter. This was continued until the student was able to give all correct definitions on three consecutive attempts. The process was then repeated for the second student.

In both groups of students, those with learning disabilities and those without, Meanings Practiced exceeded all other treatments (Pany et al., 1982). In addition, the practice condition produced positive transfer of meaning to individual sentence comprehension. Interestingly, on a delayed retention test, results were similar to immediate tests except that learning from context produced no retention of meanings. A third study of students identified as low SES and served in LD programs (N = 10) rendered similar results (Pany et al., 1982). Analysis showed significant differences between the two groups on vocabulary and sentence completion tests combined. However, although there was a significant difference on Comprehension Questions, there was not a significant difference for Story Retell or on Cloze Sentences. Even so, the authors concluded, “the effects were striking, with students achieving nearly perfect performance on both the vocabulary and the sentence measures” (Pany et al., 1982, p. 213) with synonym practice.

Use of Context Clues

Many educators believe that learning vocabulary through context increases vocabulary acquisition and long-term retention. However, studies about the effectiveness of using context clues while reading to increase general vocabulary have yielded mixed results.

A study by Nagy et al. (1987) explored learning vocabulary through incidental reading of expository and narrative text. Third, fifth, and seventh graders (N = 352) read grade-level texts and then were tested on vocabulary knowledge. Students were randomly assigned to read either an expository text or a narrative text. There was no control group for this study. When students were post-tested for vocabulary acquisition due to incidental reading, small but reliable gains were found at all grade levels. Students did learn a small amount of words through context only, but no learning of the most difficult words in the passages occurred. The majority of words learned from context were usually the easy words found in narrative text. Learning from context was most influenced by the amount of unfamiliar words and the length of the words.

Similarly, Pany et al. (1982) reported the least amount of vocabulary retention when words were learned through context. In addition, this study showed that retention of vocabulary on a delayed post-test when words were presented through context clues resulted in no learning of words. These two studies resulted in some learning of vocabulary words; however, both indicated that learning vocabulary through context, especially for delayed retention, did not show significant gains (Nagy et al., 1987; Pany et al., 1982).

Corroborating these early studies, Swanborn and de Glopper (1999) conducted a meta-analysis of 20 experiments showing that students learn only approximately 15% of the unknown words they come across during reading. More recently, researchers have examined the use of contextual-based instruction combined with different curricula and other instructional strategies. Nelson and Stage (2007) examined the results of increasing vocabulary knowledge through contextual-based instruction embedded within standard curriculum compared to standard instruction in language arts. This study included third and fifth graders (N = 238). Generally positive results were found using context to increase vocabulary knowledge. The meanings of the vocabulary words targeted in the study were presented in six varied contextual opportunities. These opportunities included introducing the words through related words to activate prior knowledge, discussing and examining the words in context and writing personal sentences about related words, examining the word history of target words, using a graphic organizers to match target words and related word definitions, engaging in activities examining multiple meanings of target words, and examining short passages that contained the target words to see if the words were used in ways that students expected or do not expect. Results indicated that generally, most students showed gains in their vocabulary knowledge from pre- to post-test. Students with the lowest initial scores improved more than students who had average to high scores on the vocabulary pre-test. And, those students who scored higher on the pre-test did not show significant educational gains. However, this might have been due to a ceiling effect within the testing instrument itself and not as a result of the intervention.

Horn and Feng (2012) looked at whether acquisition of vocabulary increased when context clues were used in conjunction with other vocabulary learning techniques during reading in order to identify the meanings of words that students did not know as measured through passage comprehension. The control group read a selection and then engaged in small-group and large-group discussion of the reading. The experimental group also read, but before reading, was provided vocabulary acquisition strategies. These strategies included activation of prior knowledge, focusing on a small number of words to be learned, encouraging the use of context clues to identify meanings of unknown words, using graphic organizers for further word development, and encouraging deep word meaning. Analysis of pre-and post-test scores indicated that there was no significant difference between experimental and control groups in reading comprehension when these strategies were used. The researchers noted that because of the link between vocabulary knowledge and reading comprehension, they assumed there was no significant difference in vocabulary gained. However, even though analysis did not indicate a significant difference in post-test comprehension, the experimental group appeared to have a larger gain in scores when comparing pre-test scores to post-test scores with the control group.

> The data showed that even though the experimental group started with a lower mean test score of 62.03, they achieved an increase of 17.83 percentage points, nearly double the increase of the control group's 9.41 points. This result has

practical significance because it seems to indicate that instruction over a period of time has a positive effect on students' learning. (Horn & Feng, 2012, p. 9)

These more recent studies looking at the effectiveness of using context clues in learning vocabulary appear to include other instructional strategies to attempt to improve learning and retention, but show mixed results.

Use of Technology

More and more studies are examining the benefit of technology and learning (Bottge, Rueda, Kwon, Grant, & LaRoque, 2009; Carnine, 1989; Suppes & Morningstar, 1969). Computer technology can support learning several ways. Several components of the computer are effective in enhancing vocabulary learning (Constantinescu, 2007). Several studies examined the benefits of using technology in learning vocabulary.

A pilot study by Ma and Kelly (2006) examined the effectiveness of a computerized vocabulary acquisition program (NUFUN) designed for individual as well as classroom use. Not only did the study examine the effectiveness of the program, it examined whether motivation influenced learning as well. Students (N = 35) were divided into two groups. Group 1 volunteered to be a part of the study and Group 2 was included in the study as a part of a self-learning class. The researchers postulated that volunteer subjects would be more motivated in learning than the subjects required to learn through a class (Ma & Kelly (2006). Pre- and post-vocabulary tests were given to subjects. Analysis included obtaining a score derived from subtracting pre-test scores from post-test scores. Information was also gathered by using questionnaires and interviews. In both groups, learners perceived words as difficult. The words assessed receptively − considered to be a lower level hierarchically in understanding, and productively − which designates knowledge at the next to highest level of understanding. The study indicated that the computerized program was able to help learners acquire vocabulary at both the productive level and at the receptive level in both groups. In fact, students showed greater growth at the receptive level. In addition, although the researchers assumed students would lack motivation for learning due to not having input into how they would study vocabulary for a particular class, both groups did equally well. Based on participant questionnaires, learner attitudes did not appear to affect the learning process. Apparently, learning in this study had to do more with what the students were actually doing in the learning process through the use of computer-assisted instruction.

A study by Kilickaya and Krajka (2010) examined the usefulness of learning vocabulary using an online vocabulary learning program compared to traditional learning methods. Students (N = 38) were divided into a control group and an experimental group. The control group learned vocabulary using more traditional methods including vocabulary notebooks, vocabulary cards, and paper dictionaries. Students in the experimental group learned words using *WordChamp Web Reader,* which incorporates hypertext-based glossing − a system that provides definitions of all words in the text in a dictionary look-up system. Experimental participants were able to find the meanings of words in academic reading passages as they read for comprehension. Analysis of pre- and post-testing indicated a statistically significant difference between experimental and control groups. Students learning vocabulary using *WordChamp* learned significantly more words than those using more paper/pencil approaches to learning. Even after a two-month delay, there was still a statistically significant difference between the groups.

Another study examining the effectiveness of WordChamp was conducted by Spiri (2008). Participants compared learning vocabulary words using a computerized drill and practice program with traditional paper study. Pre- and post-test quiz scores were examined from the two groups. Students (N = 20) were given 30 words to learn for the experiment. The control group was given the words and definitions to be learned on paper. They were told to learn the words using drill and practice. It was suggested to the control group that they cover the vocabulary words and try to remember the words that were covered. They were also encouraged to either write their words in a vocabulary notebook or make flashcards. The students were also reminded that it was more effective to study more often in shorter chunks than to study for longer periods of time. Students in the experimental group used an on-line study program, *WordChamp* to practice the target words. These students used, *Absolute Recall*, the drill and practice portion of the program. *WordChamp* bases its study strategy on a modified Leitner System. The Leitner System is a system that organizes words into groups to be studied based on the successful learning of the words. Words that are missed are presented more often in order to allow repetition until mastery. Words are presented randomly and then grouped as students use the program to learn. In this study students were tested after four weeks of studying. Analysis showed that students who studied using *WordChamp* performed better than students who studied using paper.

Another study by Johnson et al. (1987) compared two methods of teaching vocabulary using computer-assisted technology. High school students (N = 25) in grades 9 through 12 were participants in the study. These students were diagnosed with learning disabilities and each scored at least three years below their grade level on the Reading subtest of the Woodcock-Johnson. Students were given a 50-item multiple choice vocabulary pre-test. Each group had a mean score of about 50%. The students were matched by pre-test scores and then randomly assigned. Students were assigned to one of the two treatments in the experiment − the Small Teaching Set program or the Large Teaching Set program. The Small Teaching Set was designed "to exemplify . . . two principles of instructional design . . . optimal set size and cumulative review" (Johnson et al., 1987, p. 207). Instructional design of the Small Teaching Set included the following features: (a) lesson based on words the student does not know, (b) practice sets with no more than seven words, (c) mastery criterion which must be met, and (d) cumulative review on learned target words for retention. The Large Teaching Set taught words in sets of 25. The students could choose to see the words in any of four formats: (a) a display that shows the word, its definition, and an example sentence; (b) a format including a multiple choice quiz; (c) an exercise where a word is missing from the definition and the student must fill in the correct missing word; and (d) an arcade-type game where the student must match words to definitions. The review portion on each set was also different. The Small Teaching Set provided daily review on words and periodic cumulative review on learned words. In the Large Teaching Set, there was no record of student errors so no cumulative review of learned words could be given. Analysis on the data showed there was no difference on the type of program used. Mean performance was close to mastery on both the post-test and the maintenance test given two weeks later for both groups − 84% and 87% on the post-test and 81% and 84% on the maintenance test. However, although the post-test scores showed no difference, significantly more students were able to learn the information in the Small Set in a shorter amount of time than students learning information in the Large Set (Johnson et al., 1987).

In order to compare these results with students identified with LD using computer-assisted vocabulary programs with students without learning difficulties, the pre-test was administered to 10th-grade students without learning difficulties in an English class that was randomly selected. The mean post-test scores of the handicapped students after computer-assisted intervention were similar to the non-handicapped students' mean scores.

> These LD students were able to learn word meanings so that, in this instance, they could perform on a level similar to that of their non-handicapped peers. The difference in performance between the LD groups and the non-handicapped group was not significant. This result indicates that, with intelligent use of CAI, the LD students performed at a level similar to their non-handicapped peers. (Johnson et al., 1987, p. 211)

Academic Vocabulary Acquisition

While the importance of vocabulary knowledge and the role it plays in reading and learning has been established, it has become more obvious that vocabulary also plays an important role in academic areas such as math, social studies, and science. Experts acknowledge the importance that subject-specific vocabulary plays in school success and life (Young, 2005).

Success in these subjects is impacted in many ways by vocabulary knowledge. "The precision of mathematical definitions often is the distinguishing factor between a vague and a clear understanding" (Carter & Dean, 2006, p. 143). Scruggs, Mastropieri, and Okolo (2008) write that social studies content can be difficult and that knowledge of social studies vocabulary “is a critical element in a subject that has its own set of discipline-specific language and principles” (p. 11). In addition,

> science is a vast and diverse content domain, and it is important to note that not all scientifically relevant information can be acquired through manipulation and inquiry. Vocabulary and terminology . . . cannot be discovered or invented but need to be learned and remembered. (Scruggs & Mastropieri, 1994, p. 318)

Not only is domain-specific vocabulary important for understanding, but it is critical for academic success due to content specific texts (Taboada, 2011). It is imperative that educators find successful ways of helping students learn domain-specific vocabulary.

Several studies examine strategies in learning subject-specific vocabulary. Many of the studies examine whether direct instruction can lead to increased academic vocabulary knowledge. In addition, although computer-assisted learning has been shown to increase learning, few studies examining vocabulary learning have been explored. This section describes some of the research exploring direct instruction and the use of technology for learning academic vocabulary.

Direct Instruction and Academic Vocabulary

An action research focused on whether academic vocabulary could be improved through direct instruction (D’Alesio et al., 2007). The direct instruction focused on a multisensory approach which included graphic organizers with visual icons, music, and movement. Participants (N = 73) were students from two 7th grade classrooms and a 2nd grade classroom. Data were collected with pre- and post-strategy surveys, a 50-word pre- and post-vocabulary tests, a reflective journal with an attitude scale, and teacher field notes.

The primary component of the study in looking at increased vocabulary knowledge was the use of a graphic organizer with enhanced visual icons (D'Alesio et al., 2007). Color was also an important component of the graphic organizers. Part of the graphic organizer was the requirement of a student drawn color illustration. Color-coded paper was used for vocabulary handouts to provide consistency. The 7th-grade version of the graphic organizer contained the following icons to help students associate the word information with a visual connection in order to help promote memory: arrow for the word, cloud for word meaning, star for student hint/clue, rectangle for word sentence, and easel for illustration. The 2nd-grade graphic organizer also looked at increasing word meaning information and was considered to be grade appropriate. A pre-test was given on Week 1 of the study in order to be able to look for growth of words not previously known. The word list was comprised of different academic-specific words from math, social studies, and science. The words were considered to be challenging by the researchers. The 7th-grade words chosen were words with SAT roots and affixes. Words for the 2nd-grade class were taken from the district required word list.

Each week teachers in the study presented vocabulary to be learned through direct instruction (D'Alesio et al., 2007). Before lessons, teachers guided students in movement in order to increase focus and memory. Next, teachers guided students in how to use a graphic organizer to enhance learning and presented the weeks' words. The study was not specific in exactly how the direct instruction occurred. Finally, as students worked, teachers played classical baroque in order to improve students' focus and recall as well as create a *sense of calmness* during lessons.

Each week a pre-test was given in order to break up the large word set and as a formative assessment for feedback for teachers and students (D'Alesio et al., 2007). Each week a set of vocabulary words was introduced to students followed by a post-test. A cumulative post-test was given at the end of the semester.

The authors reported that results indicated substantial growth in knowledge of academic vocabulary (D'Alesio et al., 2007). On the pre-test 10% of the students demonstrated an understanding of the words. On the post-test, 53% of the students showed understanding. The results showed that students understood and could define more than five times as many words. In the beginning of the intervention the students knew 378 words and by the time they were post tested at the end of the intervention they knew 1,941 words (D'Alesio et al., 2007). The researchers did acknowledge that it was difficult to tell exactly what influenced the increase in knowledge due to the number of variables in the study and the lack of controls.

Upadhyay and DeFranco (2008) conducted a study that compared 3rd-grade students' gain of science vocabulary as well as retention over time by using two different techniques − connected science learning versus direct instruction. The study was implemented at two different schools from two large urban districts in the Midwestern part of the U.S. Approximately one-quarter of the students qualified for free or reduced lunch. Participants in the study (N = 108) were from two 3rd-grade classes from each school. The researchers chose classrooms that were comparable in size, demographic makeup, and common curriculum in order to decrease any confounding effects of possible variables (Upadhyay & DeFranco, 2008). The classrooms were designated as either treatment groups or control groups. The treatment groups were taught science vocabulary and concepts using connected science. The researchers provided teachers of the treatment groups with resources to teach connected science (Upadhyay & DeFranco, 2008). Supplementary materials provided to the teachers were designed to give teachers content knowledge and pedagogy in order to teach environmental science. Two 3-day workshops were also provided to help the teachers learn to connect science with their students' experiences and lives. The control group teachers were instructed to teach environmental science using direct instruction. They were told not to connect the lessons to their students' lives but to use teacher-centered methods. The teachers were encouraged to use hands-on activities, but in a way that they would provide all instructions, including correct answers, to the activities. All teachers taught a unit on environment earth science for eight weeks. They were asked not to teach environmental science in any other subjects. Data were collected through pre- and post-assessments. A pre-assessment was given before exposure to the units, the post-assessment was given immediately after completion, and a retention assessment was given three months after the post-assessment to assess long-term retention of science knowledge retained from the intervention. Analysis of the data conducted by a repeated-measure ANOVA indicated that students who learned science vocabulary through connected science showed less gain in knowledge in the short term as compared to students who learned through direct instruction. In the control (direct instruction) group, there was a significant gain from pre- to post-test. However, when looking at longer retention of information, those students who learned from connected science showed a lower rate of loss than students who received direct instruction.

A study by McAdams (2012) explored the effectiveness of direct instruction on math and science vocabulary student achievement. The study took place in an ethnically diverse suburban school in north central Texas. Classes were formed randomly before the school year began and divided into experimental group (N = 58) and control group (N = 56). The study included students from the general population as well as students that were economically disadvantaged and students identified as at-risk. Each group was taught the same educational objectives but the experimental group received direct instruction of math and science vocabulary terms associated with the objectives. Direct instruction was given through the use of the Vocabulary Builder graphic organizer.

As vocabulary was introduced through classroom lessons, each student completed Vocabulary Builders on 3 x 5 cards (McAdams, 2012). As the year progressed, students grouped the cards by unit of study. Students in the experimental group were encouraged to review their vocabulary cards when preparing for a test or when learning new information and connecting it to previously learned information. The teacher also encouraged peer interactions including discussions of words and asking for help if necessary. Students in the control group did not receive direct instruction of vocabulary terms. The control group was taught lessons based on the district curriculum and pre-taught vocabulary words before each unit. In this study, no statistically significant differences in students' performance on the fifth grade state standardized math assessment were found between experimental and control groups. However, the author did indicate that economically disadvantaged students performed better on the fifth grade state science test when they received direct instruction in science vocabulary (McAdams, 2012).

Computer-Assisted Instruction and Academic Vocabulary

A study by Salsbury (2006) examined two types of instruction when teaching geography − teacher directed learning and computer-assisted learning. Although Salsbury (2006) reported that both methods have been shown to be effective, he wanted to see how both methods compared to each other in teaching geographic place name vocabulary. In this study, students were expected to learn (identify and locate) 50 world places. Participants (N = 68) were fourth grade students from a suburban school in the Midwest. The students could not be reassigned into randomly selected groups so were used as they had been assigned for the school year. However, demographics of the classes used in the study represented demographics of the school. Students were divided into three types of groups: teacher-directed, computer-assisted, and control. Although teacher directed and computer-assisted were two separate groups, both groups employed direct instruction as a type of instruction. Therefore, the study was mainly exploring the differences between direct instruction given by a teacher or delivered by a computer. “The use of detailed scripts for both methods emphasized the characteristics of direct instruction through clearly stated instructional goals, organized content focus, immediately provided feedback, and tightly structured instruction” (Salsbury, 2006, p. 149). The control group received no vocabulary instruction. All groups were given a pre-test, *50 World Places*, before the intervention started. Both experimental groups engaged in the study received instruction 15 minutes a day for 10 days. Intervention involved reviewing the previous day’s facts plus learning the new facts of the day. On the last day of the study, all three groups took a post-test. An analysis of variances was used to examine the data between groups. The significance between post-test scores was found to be highly significant at .0001. Both the teacher-directed group and the computer-assisted group showed statistical significance when compared to the control group. However, computer-assisted instruction showed higher gains of pre-test to post-test compared to teacher-directed instruction. The researcher felt that one factor that might have contributed to the increased scores for computer-assisted instruction was student motivation (Salsbury, 2006). However, the researcher felt that although there may have been other factors influencing the results, it was the type of instruction used in the study that appeared to be the prime reason for the increased scores (Salbury, 2006).

A study by Muehrer, Jenson, Friedberg, and Husain (2012) examined whether technology could significantly increase the science vocabulary knowledge of secondary students. The participants (N = 161) played science computer games that were focused on life of a plant and the associated vocabulary. The games in this study were created by Spongelab Interactive, a Canadian game developer. Spongelab Interactive "aims to intervene in the declining enrollment (and interest) in science by developing science-themed digital games" (Muehrer et al., 2012, p. 4). Four mini-games were used in this study. The games were accessed online through a web browser. The games used animation, custom audio, and graphics. Throughout game play, a variety of formative data were collected that could provide teachers with information about their students' progress and level of engagement.

The participants in the study, from five different schools, played at least one of the games during the intervention time, but could play up to three (Muehrer et al., 2012). The participants partook in approximately eight hours of game time. The number of days that classrooms participated, and the decision of which games to be played depended on each individual teacher. The games used strategies such as tutorials, repetition through play, problem solving, and narrated animations to foster learning. Classrooms that participated were divided into two groups: one group received an introductory 10-minute lesson covering the material while the other group did not. This addition was used to see if students needed a pre-intervention background in order to successfully play the games and learn new content. Each group played the games for 30-40 minutes. Several different methods of gathering data were used (Muehrer et al., 2012).

In order to analyze whether vocabulary knowledge increased, pre- and post-tests were given (N = 147) (Muehrer et al., 2012). The pre- and post-tests were based on biology curriculum (grades 8-10) and game content. Each quiz had 10 questions. Although students at the different testing sites all participated in the game-playing, successful sessions were varied. The researchers wrote,

> Our measure of a successful gaming session included many or all of the following conditions: (1) the students played the game for most of the period; (2) the students talked to each other about the game; (3) the students attempted to play and win all the levels of the games assigned to them; (4) the students challenged each other; (5) the students independently, or in groups, attempted to solve the problems posed to them in the game or problems that arose with the technology; and (6) the students were able to vocalize some or all of the processes that were being illustrated while they played the game. (Muehrer et al., 2012, p. 10)

Results showed that students were able to retain vocabulary learned from playing the game. The majority of the students (53%) improved their vocabulary knowledge by playing the computerized game. On one campus 100% of the students improved their pre-test score. Paired t-tests were used to compare the within-subjects difference in pre- and post-quiz scores. The difference in scores for Lesson 2 (“The Light Reaction Game” and “The Calvin Cycle Game”) indicated a statistically significant difference (.001). In addition, in an interview with students after game playing, students said they would use the vocabulary learned from the game many times. There was no difference in scores between students who had pre-game lessons and those that did not. Students learned just as many words when playing the game without a formal lesson introducing the vocabulary and concepts of the game. This indicated that the game could be used as a separate activity as well as an integrated part of a specific lesson.

The *point and click, drag and drop* type of play was successful in increasing vocabulary knowledge. Simulation games were less successful in helping students have a true understanding of more complicated concepts. Although each class used a certain level of difficulty of the game − applied, academic, or enriched − the authors wrote that it was not the category of play that appeared to influence student engagement or success in playing the game (Muehrer et al., 2012). They felt it was classroom dynamics − especially a student's ability to show patience and persistence in playing the game even if the technology did not work.

One interesting finding in the study was that student engagement or enthusiasm, gathered through 21 hours of audio/video recordings and selectively transcribed by the researchers, was not always an indicator of student success as evidenced by their improved post-test scores (Muehrer et al., 2012). The class that showed the most improvement in post-test scores was also the room with the least engagement − a noisy computer lab with students talking about things other than topics related to the games. The authors felt that because this class could be successful even without being fully engaged, this demonstrated the excellent ability of the computer game to review information (Muehrer et al., 2012). This computer game seemed to engage students enough to increase learning whether students had a positive attitude toward learning or whether they were fully engaged. In this study, the authors concluded that the most important aspect was not just the use of technology but the software being used (Muehrer et al., 2012).

Gaps in Previous Studies

Professionals agree that vocabulary, both general and academic-specific, is important to knowledge and success in school. However, when examining previous studies, while there are studies that show significant gains with vocabulary instruction, there are also some inconsistencies and some gaps. There were mixed results when looking at the success of using context clues for vocabulary learning. Most of the studies in this literature review corroborated a meta-analysis that reported students learn very few words by context alone (Swanborn & de Glopper, 1999).

While many of the studies acknowledged the importance of direct instruction in increasing vocabulary knowledge, several of the studies included other variables as a part of the study which made it difficult or impossible to determine whether direct instruction was the direct cause of an increase in learning. For example, Dietrich (2008) reported a significant increase in vocabulary acquisition when using direct instruction as compared to the control group. However, in addition to explicit direct instruction, students also participated in read-alouds and story reading. August et al. (2009) incorporated hands-on activities as well as scaffolding techniques as a part of their study examining direct instruction. Scaffolding techniques included illustrations of vocabulary concepts and graphic organizers, previewing of the activities, and matching ELL students with English proficient students who served as language models. In addition, professional development was provided to the teachers working with the experimental group. Other studies that included additional variables in addition to direct instruction included Nelson and Stage (2007) who added pre/activities for prior knowledge, word history, and word maps and D'Alesio et al. (2007) who added music and movement to their direct instruction study.

There was also an inconsistency in how many participants were involved in each of the studies. While several of the studies had large samples such as Nagy et al. (1987) (N = 352), Nelson and Stage (2007) (N = 238), and Muehrer et al. (2012) (N = 161), some of the studies had very small numbers of participants, decreasing the power of the study and lowering the magnitude of the findings. Pany et al. (1982) had the lowest number of participants (N = 12, N = 6, N = 10) across three different studies. Although somewhat higher, the following studies' results should be viewed with caution: Spiri (2008) (N = 20), Johnson et al. (1987) (N = 25), Dietrich (2008) (N = 25), Ma and Kelly (2006) (N = 35), and Kilickaya and Krajka (2010) (N = 38).

With the latest research showing positive results using technology to increase learning, the biggest gap in the literature is the small number of studies using technology or computer-assisted instruction to teach academic vocabulary. Only Salsbury (2006), who examined the acquisition of geography vocabulary using technology, and Muehrer et al. (2012), who studied varied uses of a computer game to increase science vocabulary and knowledge with secondary students, combined computer-assisted instruction with academic-specific vocabulary learning.

Learning Theory Related to Knowledge Acquisition

Principles of learning theory provide a foundation for best practices in vocabulary acquisition. Instructional design, whose principles are based in behaviorism, provides a basis for exploring vocabulary learning. Behavioral theory posits that learning occurs when there has been a change in behavior. Formally it is defined as “a change in the likelihood or probability of a response” (Gredler, 2001, p. 90). Within behaviorism’s tenets, learning focuses on changes that are observable rather than changes that involve cognitive or mental processes (McCown & Roop, 1992). B. F. Skinner, well known for his operant conditioning, believed that by manipulating the environment, behavior could be shaped in a desired way (Snowman & Biehler, 2000). Skinner also felt that consequences that followed influenced whether certain behaviors were repeated and how intensely (Snowman & Biehler, 2000). In addition, Skinner (1986) believed that individuals could be *told* how to do something which led to a changed behavior. He felt that *showing* and *telling* prepared individuals to behave in certain ways in the beginning so that particular behaviors could be followed later by reinforcers.

Skinner’s theory has many parts that match the criteria for a good theory:

> It is a well-defined, highly researched system that reflects the facts, especially as they relate to the relationships between reinforcing events and the characteristics of responding. It is a clear and understandable system that not only explains some aspects of behavior remarkably well but also allows predictions that can be verified. (Lefrancois, 2000, p. 130)

Direct Instruction Model

The direct instruction model has been used as a successful instructional strategy for many years. Based in behaviorism, which stresses that learning occurs when a behavior is changed (Gredler, 2001), direct instruction focuses the learner on what is most important to be learned. When the information has been reviewed enough then learning occurs. Learning occurs through repetition so that automaticity, the ability to do something automatically, occurs (Jordan & Porath, 2006). The threshold for learning is different for each individual. Because of this, individualized instruction based on different learner needs is important in the learning process (Gredler, 2001). "A direct instruction approach is a learning process, a method and a model that designs, prepares, presents, deals, and manages several organized steps, procedures, and techniques . . ." in the learning process (Al-Shammari et al., 2008, p. 82). Many researchers found direct instruction to be advantageous over other different interventions for learning information (Gujjar, 2007; Jintendra, Edwards, Sacks, & Jacobson, 2004; Pany et al., 1982). Gujjar (2007) concluded that direct instruction is a very useful model to be used with students with difficulties in learning across subject areas.

The direct instruction model is also useful for technology-based instruction that is used today for academic practice and learning. It is well-suited because of the clear structure and ability to provide learners with guided practice, remediation, and immediate feedback. Computerized direct instruction is the model of choice when the objective of the learner is to learn information that requires direct instruction (Magliaro et al., 2005)

Direct instruction works particularly well with learning vocabulary (Baker et al., 1995). More specifically, explaining a word unquestionably is much more effective if you want a student to learn a word than waiting for that student to encounter the word numerous times through context (Nagy & Scott, 2000).

Reinforcement Theory

In behaviorism, a change in behavior is the evidence that learning has occurred. Important to operant conditioning is the premise that a reinforcer follows a response (Jordan & Porath, 2006). Skinner (1986) proposed that these changes occur through reinforcers.

Reinforcers can be pleasant or unpleasant (Skinner, 1986). Something pleasant causes the behavior to increase and punishers − something unpleasant, causes the behavior to decrease. In learning theory based on behaviorism, the teacher must establish the reinforcers that increase students' learning (Joyce & Weil, 1996).

Skinner (1986) also believed that complex learning could occur within behaviorism's tenets. Complex learning occurs as a result of "complex and subtle contingencies of reinforcement" (Gredler, 2001, p. 101). These subtle reinforcers are not always obvious and therefore it may appear that the behavior was not influenced by outside reinforcers. Skinner called these individual reinforced changes leading to complex behaviors *shaping* (Gredler, 2001). In shaping, rather than being left to chance, behavior or learning is influenced by small reinforced changes that pave the way for the next step in the learning sequence (Gredler, 2001). The key components of shaping complex skills include:

> (a) inducing a response; (b) reinforcing subtle improvements or refinements in the behavior; (c) providing for the transfer of stimulus control by gradually withdrawing the prompts or cues; and (d) scheduling reinforcements so that the ratio of reinforcements to responses gradually increases and natural reinforcers can maintain the behavior. (Gredler, 2001, p. 110)

Mastery Learning

Behaviorists believe that individuals are capable of learning as long as the information is broken down and presented in a way that promotes mastery of the skill by the individual. Mastery learning, based on John Carroll's model, states "it is important to specify outcomes, facilitate motivation, and provide appropriate materials. What is unique to the mastery approach is that it facilitates the presentation of materials at rates appropriate to each student" (McCown & Roop, 1992, p. 415). Another very important component of Carroll's mastery learning is the rate at which each child learns (McCown & Roop, 1992).

Skinner (1984) wrote there are four solutions to teaching students that would solve problems in education: "Be clear about what is to be taught. Teach first things first. Stop making all students advance at essentially the same rate. Program the subject matter" (p. 951). These tenets support mastery learning in the learning process. Mastery learning includes: (a) objectives are specified for learning, (b) information is presented in small units, (c) information is presented sequentially, (d) practice is an important component, (e) feedback is immediate, (f) mastery is obtained before moving on, and (g) data were used to determine what remediation is needed if mastery is not reached (Magliaro et al., 2005; Ormrod, 2008; Wambugu & Changeiywu, 2007).

Skinner (1986) wrote, "Good instruction programs maximize the effect of success as a conditioned reinforcer by asking students to take very small steps and by making every effort to help them do so successfully" (p. 108). A study by Wambugu and Changeiywu (2007) showed evidence that achievement increases when using mastery learning. Based on their findings the authors felt that if mastery learning was used, more students would choose to take science courses such as physics (Wambugu & Changeiywu, 2007). Benefits of mastery learning include reduced amount of time to achieve mastery (Wambugu & Changeiywu, 2007), increased motivation (Skinner, 1984), and using the natural diversities found within groups of students in order to differentiate (Wambugu & Changeiywu, 2007).

Computer-Assisted Technology

Computer-assisted technology lends itself especially well to instructional design. Using technology for learning combines the principles of direct instruction, reinforcement, and mastery learning into a method for increasing individual learning. Skinner (1986) believed the computer was the "ideal hardware for programmed instruction" (p. 110). Skinner's premise for teaching was that learning in individuals should be shaped (Snowman & Biehler, 2000). The materials to be learned and the consequences that followed should be designed so that students are led step by step to an end result predetermined before the lesson begins. This approach was known as programmed instruction (Snowman & Biehler, 2000). In addition, Skinner believed that technology could provide unlimited reinforcers that would lead to changed behavior, something that one teacher could not possibly do for a classroom of students (Gredler, 2001).

Computer-assisted instruction has many benefits that are based in behaviorism and that increase student learning. Computer-assisted instruction provides practice opportunities for students that need additional practice (Bryant, Goodwin, Bryant & Higgins, 2003). Computer-assisted instruction can increase the possibilities of potential reinforcers (Gredler, 2001). Computer-assisted instruction allows students to move forward in their learning as soon as they are ready (Skinner, 1986). Computer-assisted instruction is particularly helpful for struggling learners and younger students (Snowman & Biehler, 2000). And, computer-assisted instruction can give appropriate feedback to varied responses (Gredler, 2001).

Technology using direct instruction approaches, such as teaching of individual skills in a guided fashion, is a proven intervention (Magliaro et al., 2005). But, the most important part of computer-assisted instruction is the program that is being used. However, excellent programs are much harder to find than not-so-good ones (Snowman & Biehler, 2000). Selecting the right program to supplement the teacher's instruction is critical (Jintendra et al., 2004).

While using computer-assisted instruction to increase vocabulary growth shows promise (Baker et al., 1995), more research is needed to discover the benefits that computer-assisted instruction has to offer (Jintendra et al., 2004). Moreover, technology should be explored because today's younger generation is a generation that has grown up using technology.

> As education in science, technology, engineering, and mathematics (STEM) begins to take priority in secondary schools in the US, a pressing issue is to figure out how to gain (and keep) the attention of students and cultivate enthusiasm for learning through a medium in which they are fluent. (Muehrer et al., 2012, para. 6)

While the studies in this literature review focused on one or two important aspects of instructional design, no one study was able to answer the question about what type of instruction is best for science vocabulary. While some of the studies examined direct instruction and some of the studies looked at technology, there was no study that examined whether computer-assisted technology can increase the science vocabulary acquisition of fourth and fifth graders as shown by an immediate post-test and a delayed post-test.

Significance of the Study

There were several gaps in the literature that must be explored when looking at computer-assisted technology and science vocabulary acquisition. First, most of the literature on direct instruction contained multiple variables. When multiple variables are included within a study it is difficult to examine the main effect of the study. Second, there are very few studies that focus on science vocabulary acquisition. Third, there are not many studies that explore using technology to increase vocabulary knowledge. Finally, in this literature review there were few studies that looked at using computer-assisted technology to increase science vocabulary.

Because instructional design provides a solid foundation for exploring the acquisition of vocabulary and because there are currently no studies that examine the effectiveness of technology in teaching science vocabulary for the fourth and fifth grades, this study examined a computer program that uses the instructional design principle of learning while incorporating direct instruction, reinforcement, and mastery learning in a computer-assisted learning game format. The results of this study will add to the literature examining computer-assisted technology and whether it can significantly improve the science vocabulary knowledge of fourth and fifth graders.

CHAPTER THREE

Research Design and Methodology

Research has shown the importance of building a base of knowledge for school success. An inability to memorize or learn information can affect students' learning (Mastropieri & Scruggs, 2007). Difficulty remembering information can lead to decreased grades and possible school failure. Today, with the emphasis on state mandated tests, it is becoming extremely important, even in the younger grades, to be able to learn content information and store it in memory. As students grow older, the complexity and amount of information to be learned becomes increasingly important to success (Wilson, Nash, & Earl, 2010). Not only does difficulty with learning information impact school, but, increasing demand in content areas where students are not successful can lead to "loss of future opportunities in society" (Mastropieri et al, 2006, p. 130).

As students get older, more of the reading that is required is presented in an expository fashion, which is more difficult to comprehend (Williams et al., 2007). Specifically, vocabulary knowledge maximizes learning in the classroom (Mastropieri & Scruggs, 2007). Science can be particularly challenging because "there is a lot of content in science that simply has to be learned through practice and time-on-task" (Whitehurst, 2004, p. 23).

Because of the importance of school success and because vocabulary plays an important role, this study examined two specific questions:

1. Is there a difference in the growth of science vocabulary between students who participate in a computerized vocabulary program versus those who participate in a traditional vocabulary review sheet?
2. Is there a difference in science vocabulary retention between students who participate in a computerized vocabulary program versus those who participate in a traditional vocabulary review sheet?

Method

Research Design

The researcher used a true experimental design for this study. Because students were randomly assigned into groups, the Pretest-Posttest Control Group Design was used. This design involves at least two groups, both of which are formed by random assignment. This design is especially advantageous because of the strength of its internal validity. Because extraneous variables affect both groups within this design equally, they are controlled for within the design ("Experimental Design," 2010; Issac & Michael, 1997).

Both groups were given a pre-test. The experimental group received a new treatment intervention while the control group used a traditional method. Both groups were post-tested. In addition, an additional post-test was given two weeks later to look for delayed or long-term retention of knowledge. Using randomization in this design helped control for confounding variables as well as increased the power of the results.

An alpha of 0.05 was used in examining statistical significance. Sample size was estimated using Kirk's (2008) table of "Approximate *n* Required for Testing Hypotheses about Means." Choosing an effect size of 0.5, a significance level of 0.05 and power of .80, the table suggested the researcher use 50 participants for each group in the study to be able to detect statistically significant results or power.

A minimum of 100 fourth and fifth grade students were necessary for the study, but more were recruited to allow for participants who drop out because of sickness or lack of interest. The researcher used two groups. The experimental group had 62 students and the control group had 63 students. Students who returned signed permission slips to participate in the study were randomly placed into groups. Each group was pre-tested. The experimental group studied science vocabulary using Study Hall 101 (Raley, 1999/2006), a computerized study intervention tool, in the study lab at the school. The control group studied using the conventional method of a study review sheet which consisted of the vocabulary words and their definitions in a classroom at the school. Practical and research considerations were used to determine the amount of days and time on task for the study. A teacher poll and research suggested six study days for approximately 40 minutes of study time would be appropriate. School personnel, who volunteered to be a part of the study including the teachers and the campus intervention specialist as well as the researcher, monitored the classrooms during the intervention time. After study intervention of five times over two weeks, a post-test was administered. A follow-up post-test was administered two weeks later.

Participants

Participants for this study were fourth and fifth grade students at a suburban school in central Texas. Demographics were taken from the Texas Education Agency's (2010-2011) website. Demographics of this school consisted of 79.8% Caucasian, 13.4%

Hispanic, 4.3% African American, 0.4% Native American, 0.2% Asian, 0.2% Pacific Islander, and 1.7% two or more races. The school's population was identified as 31.9% economically disadvantaged, 0.8% was identified as Limited English Proficient (LEP), and 26.7% was identified as At-Risk. Students with disciplinary placement included 0.8% of the population. Students coded under Mobility were 12.3%. Special populations included gifted and talented, 15.9%; special education, 9.1%; and Bilingual/ESL 0.8%. As reported in TEA's Adequate Yearly Progress (AYP) District Data Table, the district had a 97.2% graduation rate. TEA awarded this district a Recognized rating. They also met AYP criteria.

Specifically, the Intermediate School, which housed fourth, fifth, and sixth grade students, had 543 students. Fourth, fifth, and sixth grades had 180, 180, and 183 students each, respectively. TEA awarded the Intermediate campus an Exemplary rating.

Students that returned signed permission slips to participate in the study were placed into two groups, experimental and control through random assignment. Students participated in the study five times over two weeks during a 40-minute period. After the first day, each student in the control group could determine the amount of time they studied individually based on how long they thought it would take to be successful on the post-test. The experimental group studied approximately 20 minutes per period after getting settled at the computer and logging on and logging off the game. The length of the study was two weeks. There was no interruption of scheduled instructional time during the study. Anonymity and confidentiality were a top concern. It was explained to participants that this study would not impact their school grades in any way. Students that participated in the study were aware that they could voluntarily drop out of the study without any penalty if they felt that they would no longer like to be a part of the study.

Students, who were reading on a first or second grade level, as indicated by school criteria, were excluded from the study. Since this study focused on science vocabulary rather than reading level, the scores of these students would not be indicative of learning science vocabulary but of their readability level. To ensure that the groups were comparable, demographic information was collected even though participants were randomly assigned.

Fourth and fifth grade students were chosen for this study for several reasons. First, fifth grade is the first year that students are tested on TAKS in the area of science. More emphasis is placed on science in these two grades than in previous years in order to prepare for the state-mandated test. In previous grades, students have only been tested in reading, math, and writing. Administrators were anxious to find a way to help students be successful on the TAKS science test and were willing to be a part of this study. Second, by fifth grade, content is becoming increasingly complex. Most students are not able to listen and remember content well enough without studying the information to be tested. Expository reading becomes more pervasive and readers, in general, have a harder time gleaning information to learn from the text without a solid knowledge of the academic vocabulary being used. Therefore, it will be beneficial for students to be studying science vocabulary that they will encounter in subsequent grades rather than a list of useless or nonsensical words. So as not to discriminate between the control group and the treatment group, the control group had the opportunity to be trained in and use Study Hall 101 (Raley, 1999/2006) as a study technique at the end of the current study.

Instruments

To measure the growth of science vocabulary the *Test of Science Vocabulary* was used (Rollins, 2011). Due to the fact that a search of science vocabulary assessments did not provide a test which was technically adequate for this study, the researcher created a test of science vocabulary that could be used for pre- and post-testing purposes. This test was a measure of science vocabulary using science words which were considered to be foundational for the discipline. The *Test of Science Vocabulary* is a 24-item science vocabulary assessment.

In order to ensure that words chosen for the study were not typically known by fourth and fifth graders, and in order to ensure that a ceiling was not reached, words for the *Test of Science Vocabulary* were chosen using 8th-grade science vocabulary and advanced science terminology.

An educational regional service center in central Texas, ESC 12, agreed to let the researcher use some of the items from assessments they had created to evaluate science vocabulary knowledge. The researcher chose vocabulary words/questions from the 8th-grade TAKS review from two sections: Motion, Force, and Energy and Structures and Properties of Matter. These sections were chosen in the belief that these vocabulary words were not as readily known by fourth and fifth graders due to the content covered. Additional words were also chosen from a list of advanced science vocabulary words (academic word list: Level 4) from Marzano and Pickering (2005). These additional upper level words were chosen to prevent a ceiling effect should there be any students that were particularly adept in science. Because the *Test of Science Vocabulary* is a new instrument, the test was piloted so that an acceptable reliability could be established.

The pilot for the *Test of Science Vocabulary* was a 100-item, multiple choice test created using science vocabulary. The questions were presented four to five questions per page in order to prevent visual clutter. The layout of the instrument included the definition presented and then four choices given for possible answers. Only one answer was correct. Fifty 5th grade students were administered the test in groups of approximately 12-15. The directions were read to the students and an opportunity for questions regarding administration was given. Students were told that test administrators could not provide help on any of the questions. Students were directed to choose one best answer. One practice item was done with the group to provide guidance in the format of the test questions. Students were then instructed to begin the test. Most students finished the pilot test in 15-20 minutes. A few students finished in 10 minutes and two students finished in 45 minutes. Test administrators circulated throughout the room during testing and checked as each test was turned in to make sure no items had been skipped.

After tests were scored an item-analysis was performed using SPSS. An initial reliability of .883 was established using Cronbach's Alpha with all 100 items of the pilot. The 24 words with the highest discrimination values were then chosen. The range of discrimination was between .635 and .360.

Reliability was performed again on the chosen 24 words using SPSS with a Cronbach's Alpha of .882. Because this represented an acceptable alpha for an achievement test, the following words were chosen to represent the science pre- and post-test for this study (Table 1):

Table 1

Words Chosen for this Study

Vocabulary Word	Item - Total Correlation
elasticity	.635
chemical bond	.627
potential energy	.624
charges	.614
heat energy	.550
convection	.526
radiant energy	.503
advection	.477
atomic number	.474
media/medium	.473
biotechnology	.464
transformation	.460
isotope	.448
wavelength	.446
frequency	.443
kinetic energy	.418
physical change	.406
wave	.396
force	.386
enzyme	.370
friction	.363
chemical change	.362
electrical energy	.362
trough	.360

Content validity was established through item discrimination as well as the use of the TAKS science reviews from Region 12 and the science vocabulary list created by Marzano and Pickering (2005). To gather more information on how both groups studied, and to control for any study variables that might affect the results of the study, qualitative information was gathered through a structured exit questionnaire at the end of the intervention. A questionnaire with the following questions was given:

1. How do you usually study for a test?
2. How long do you usually study for a test?
3. What information do you usually study for a test?
4. How do you know when to stop studying?
5. How would you rate this Study Hall 101 or study guide in helping you learn the information?
6. How do you think you did on the vocabulary test you took?
7. If you study for your next test at school using (Study Hall 101 or this study guide), what grade do you think you would make on the test?
8. Reflecting on all the ways that you have studied in the past, what study tool will you use when you study for your next test at school?
9. Would you tell your friends about this study tool as a good way to study?
10. What would you tell your friends about this study tool as a way to study?
11. Is there anything else you would like to say about this study tool?

Interventions

The control and experimental groups both learned science vocabulary words and their definitions. However, the control group used the traditional method of a vocabulary review sheet and the experimental group used a computerized intervention named Study Hall 101 (Raley, 1999/2006).

Vocabulary Review Sheet

Traditionally, in this school teachers give students a review sheet in order to study for a test. In this study, the control group used a study review sheet that had the 24 science vocabulary words and definitions printed on the sheet. The students were allowed to use this sheet to study for the post-test. Test proctors were not allowed to help students in the studying of the words. Proctors were not allowed to prompt students to study or redirect off-task behavior unless it was disruptive to others. The students were instructed to study the words and definitions during each study session. Sheets were then taken up and passed back out at the next study session.

Study Hall 101

Study Hall 101 (Raley, 1999/2006) is an interactive, computer study tool used to increase specific knowledge. The computer program allows information to be individualized for personal success. The program is an engaging and interactive study intervention helping students learn facts through repeated exposures without frustration or humiliation. This program allows teachers to input their own information, thus individualizing it to their specific curriculum. Teacher-selected material is presented to students in a game-like format. In an interview, Raley suggested that the self-checking software that requires a student to retrieve the information quickly as well as accurately before moving forward in the game ensures that the information is stored in long-term memory (personal communication, January 5, 2012). Raley also suggested that requiring the student to retrieve information quickly increases learning toward automaticity (personal communication, January 5, 2012). This PC-based software has been used in the Grand Central Station model (Center for Learning and Development, Waco, TX) learning labs on campuses all across Texas. It is available for individual computer systems or can be obtained as a site-based tool.

Raley (personal communication, January 5, 2012) described the four main tenets of the program, which are built upon direct instruction and mastery learning. First, the program incorporates chunking, breaking down the 24 facts to be learned into smaller units. The student focuses on three facts to be learned at a time. Once successful, the program adds three new facts, building upon the success of the previous information. Second, it provides immediate feedback using visual and auditory cues as to whether correct answers have been chosen. Third, Study Hall 101 incorporates automaticity (Raley, 1999/2006). It incorporates review throughout the program as well as requires the student to provide information quickly. This enhances long-term memory. And, fourth, students must decide whether they have really learned what they are supposed to be learning.

Pre-test

All students in each of the groups were given the same pre-test. One student who was absent the day of the pre-test was dropped from the study because she was absent several days in a row. Students marked directly on the test booklet. The researcher graded all pre-tests. Pre-test scores were recorded.

Intervention Description

Each group was going to meet once before the study began to receive instructions on how to use the intervention for that group. However, because of field trips, the researcher used the first 10 minutes of the first day of the study to explain the interventions. Once instruction on how to study using the review sheet and Study Hall 101 (Raley, 1999/2006) was complete, both groups began studying during the designated time to begin the study. The same words were used for both groups to ensure the equality of information to be learned. Each group was given 40 minutes five times over a two-week period to study the vocabulary words. Although teachers monitored the classroom during study time, they did not encourage actual studying. However, all teachers were available for questions on use of the study strategy.

Training

Teachers monitoring the control group were instructed to not encourage studying. It was emphasized that these teachers should maintain a safe learning environment in order to decrease any anxiety over learning vocabulary words. The monitors also monitored students so that no students disrupted the study time of another student. If a student continually disrupted the study environment then that student would have been removed from the room and dropped from the study; however, there were no issues with behavioral problems. The goal during the study time was independent studying.

Teachers of the treatment group were taught how to play Study Hall 101 (Raley, 1999/2006). They were instructed on how to interact with the software as well as how to move through the different screens of the software. It was emphasized that these teachers should maintain a safe learning environment in order to decrease any anxiety over playing a new computer game.

The researcher taught the students how to play Study Hall 101 (Raley, 1999/2006) to ensure fidelity. Questions were encouraged and practice allowed with the first play screen of the game until all students felt comfortable with the process. After initial group instruction, the teacher was available for one-on-one help until all students felt comfortable in using Study Hall 101 (Raley, 1999/2006). The goal was independent players.

Post-test and Post-test with 2-week Interval

After the 2-week study period both groups, control and treatment, were given the same post-test using the Test of Vocabulary-S (Rollins, 2011). Once again, students were allowed to mark answers on the test booklet. The researcher scored all tests. After a two week delay interval, both of the groups, control and treatment, were given the same 2-week post-test using the *Test of Science Vocabulary*. This delayed post-test was administered to examine the effect of both study strategies on long term memory.

Procedure

To begin this study, permission was acquired from the school district to conduct the study on the Intermediate Campus. Conversations with the campus principal indicated that improving science TAKS scores was a focus for not only this individual campus but for the district as a whole. The *Test of Science Vocabulary* was piloted and chosen as an appropriate assessment instrument to measure knowledge of science vocabulary.

IRB approval was granted by Baylor University. Science vocabulary words were imported into Study Hall 101 (Raley, 1999/2006) by the school district's technology specialist and a study review sheet with vocabulary words and definitions was created.

Students were given permission slips to be signed by parents allowing them to participate in the study. All students who returned permission slips and that were included in the study were given a pre-test of the 24 vocabulary words and definitions to be learned in the study (Appendix). Non-readers were not a part of the subject pool.

Students were randomly chosen and then randomly assigned to be in either the control group or the experimental group. Implementation of the study then began. The experimental group received the intervention, Study Hall 101 (Raley, 1999/2006), to learn the vocabulary words and the control group learned the words using a study sheet. This took place five times over a two-week period. Each period lasted approximately 40 minutes. However the amount of time students studied varied. After the first day, students in the control group could each determine the amount of time they studied individually based on how long they thought it would take to be successful on the post-test. The control group was also told that those students who scored an 85 or above on the post-test would have their name put in a drawing to be compensated with an iTunes gift card. The experimental group studied approximately 20 minutes per period after getting settled at the computer and logging on and logging off the game.

The post-test was administered to both the control and experimental group. Exit questionnaires were administered to both the experimental group and the control group. The delayed post-test was then administered to both groups two weeks later. Analysis of the data was run and the results were recorded.

Data Analysis

To address the two questions, a mixed repeated measures 2 x 3 ANOVA was used to analyze the data. Specifically, an ANOVA was used to look at the differences between groups in growth of vocabulary and retention of the words. Because an ANOVA tells the researcher only that the groups are not the same, a test using multiple comparisons was needed to determine how the groups differed.

Because an additional post-test 2 weeks out was given to look at retention of knowledge, there were three repeated measures. Because the more times a t-test is run it increases the probability of Type I error, it was better to perform a repeated measures ANOVA.

The design was a 2 x 3 model because there were 2 groups with 3 repeated measures (pre/post1 and post2). Using descriptive statistics, the exit questionnaires were examined to determine if any factors may have influenced the results of the study.

CHAPTER FOUR

Results

Purpose and Questions

The purpose of the study was to explore whether students learn more science vocabulary words using computer-assisted learning or a more traditional method of a review sheet. A true experimental design was used. Subjects were randomly selected to participate in the study and then randomly assigned to either experimental or control groups. A mixed model 2 x 3 ANOVA analysis was used to assess differences. The research questions were:

1. Is there a difference in the growth of science vocabulary between students who participate in a computerized vocabulary program versus those who participate in a traditional vocabulary review sheet?
2. Is there a difference in science vocabulary retention between students who participate in a computerized vocabulary program versus those who participate in a traditional vocabulary review sheet?

The results of the study in this section are organized to address the research questions related to differences in the treatment and control groups' short-term growth in science vocabulary and in their long-term retention of science vocabulary.

Design of Study

Students in this study were fourth and fifth graders from a suburban school in central Texas. There were a total of 125 students used in the analysis of this current study. The students that participated in the study were randomly chosen and assigned to either the experimental or control group. There were 62 students in the experimental group and 63 students in the control group. Students participated in the study during their specials time at school so no core instruction was missed by students participating in the study. Students in both the experimental and control group were given a pre-test assessing prior science vocabulary knowledge. Students were then given a post-test and a delayed post-test two weeks later following the experimental condition. Both groups learned the same 24 science vocabulary words over a two-week time period. Students had the opportunity to study for 40 minutes on five different days for a total of 200 possible minutes.

The decision on the length of the study was a result of polling teachers and examining the research. Before the study began, the researcher polled teachers that were using Study Hall 101 (Raley, 1999/2006) with their students in a learning lab environment. The researcher asked the teachers to give input on the typical length of time that it took most students to learn vocabulary while playing Study Hall 101 (Raley, 1999/2006). The majority of the teachers indicated that most of their students could successfully learn 24 vocabulary words in approximately a six-day period working in 40-minute time periods. In addition, when examining studies in the literature for amounts of time spent learning vocabulary (Fontana et al., 2007; Terrill, Scruggs, & Mastropieri, 2004; Scruggs, Mastropieri, Berkeley, & Marshak, 2010), the average amount of time reported for learning vocabulary words was five days. The researcher decided that this information indicated that a five- to six-day study period would be appropriate for the subjects of this study. The days of the intervention were spread over a two-week period in a way that fit best with the participating school's schedule. The study had to fit within the timeframe of when the students had specials time (music, art, etc.) and when the computer lab was available.

The computer game, Study Hall 101 (Raley, 1999/2006), used by the experimental group provided interactive opportunities to learn science vocabulary words through practice and mastery learning. Students were provided a quiet environment in the school's computer lab to learn the words through game-play. Each participant wore earphones to hear the interactive noises used to provide immediate feedback as well as to not bother other students playing the game.

Each review sheet used by the control group contained the words and definitions to be learned. All 24 words and definitions were printed on one side of the paper. Students studied individually in a classroom reserved for the control group. The teacher monitoring the classroom maintained a quiet atmosphere for studying.

While several of the studies discussed previously in Chapter Two had multiple variables within the design of the interventions, this study focused on keeping variables between the two groups as similar as possible so that the results would be a function of the design of the intervention. The focus of the study examined the learning of science of vocabulary words between two different groups. The experimental group learned science vocabulary using computer-assisted learning and the control group used a paper review sheet which is often used in schools. The vocabulary words learned during the study were level eighth grade and above science vocabulary words. The words were taken from TAKS study material created by a regional education service center and from Marzano and Pickering's (2005) advanced (Level 4 - grades 9-12) science word list. Advanced words were incorporated into the study so the assessment would not have a ceiling effect for those students with higher levels of science knowledge. Students studied the words five days for approximately 40 minutes each day. The days were spread over a two-week period. A pre-test was given to all students, regardless of the group they were in, prior to the intervention to assess prior knowledge and to look for differences between the groups. An immediate post-test was given to all participants the day after the intervention concluded. A delayed post-test was given to all students two weeks later to examine long-term retention differences.

The experimental group played Study Hall 101 (Raley, 1999/2006), a computer game designed to increase vocabulary knowledge. Study Hall 101 (Raley, 1999/2006) is a standalone game therefore it does not need internet access for play. The students played Study Hall 101(Raley, 1999/2006) in one of their computer labs at school. The school had a site license for Study Hall 101 (Raley, 1999/2006) which allowed the game to be installed on every computer in the lab using a school-wide server. Because the program is not a web-based game connecting to the internet, dealing with connection problems was not an issue as is sometimes the case with web-based games (Muehrer et al., 2012). Study Hall 101 (Raley, 1999/2006) incorporated visuals and sounds for immediate feedback. It was designed to increase learning through repetition, practice, immediate feedback, and mastery learning. The game also provided an opportunity for testing knowledge at the end of play for formative assessment information. The game-play during the study used 24 science vocabulary words and their definitions.

The control group used a traditional study review sheet to learn the same 24 science vocabulary words. All 24 words were on one page. Each day when students entered the classroom they were given the review sheet to study. Students were not allowed to take the review sheet home to study. Students in the control group were not allowed to use other types of study strategies while studying (i.e. collaboration, visual mnemonics, graphic organizers, etc.). The intervention strategy for the control group was the study review sheet.

Both groups had assigned teachers that had agreed to help with the study. These teachers monitored the classrooms during the study. These teachers were instructed not to help the students with any study assistance. They also were instructed not to redirect students who were off task unless they were bothering another student in the study. The researcher was at the school for the first two days of the intervention to introduce the interventions and to be there in case there were any technology difficulties in the computer lab. The researcher also monitored during the intervention time on several days of the study. The researcher periodically walked through both conditions and monitored the studying of both groups. The intervention coordinator at the school where the study took place was available for questions or problem-solving during the study as well. The intervention coordinator was the intermediary between the school and the researcher so that students' data could remain anonymous throughout the study.

Due to unforeseen circumstances three modifications had to be made in the study during the course of the intervention. However, it is felt that none of the modifications negatively impacted the efficacy of the study. Students in the control group became unhappy during their study time. The students in the control group were motivated the first day of studying. However, after realizing that the experimental group was studying using a computer game, the control group decided that studying using a review sheet was not rewarding. After day one of the study the teacher in the control group room told the researcher that several of the students had been talking after class and at lunch and had decided they would all drop out of the study. Because of this, the following revisions were made in order to keep students in the study: 1) the study was changed from six days of study time to five for both experimental and control groups, 2) instead of being required to study the entire 40-minute time period, the control group was told they could study as long as they felt they needed in order to make the best grade possible on the post-test; when they felt they had studied enough they could then have free time the rest of the study time. The students were also told that those students who scored an 85 or higher on the post-test would have their name put into a drawing for an iTunes card. These revisions allowed students the opportunity to stop studying when they felt successful rather than being told to study for a specific amount of time, and 3) a few students in the experimental group were able to complete the game and start again in a shorter amount of time than the other students. After several times of playing the game all the way through, the students were able to make a high grade (85 or above) on the formative quiz and grew tired of reviewing the same words. A change was made that let students that were able to take the formative assessment three times in a row with a score of 85 or better use their time in the computer lab with free-time play rather than continuing to study with Study Hall 101 (Raley, 1999/2006). This helped with the motivation of these quick-to-learn students.

Changing the number of days that students studied from six to five, allowing students free time after studying, and offering the possibility of being compensated with an iTunes card alleviated the issue of the control group wanting to drop out of the study. Moreover, allowing student choice of deciding the amount of time to study was more representative of how students actually study. Students typically study until they feel that they have learned the material − not for a specified amount of time.

In the study the control group students began studying at the beginning of the class and then chose when to quit studying the words. Each student wrote down the number of minutes he or she studied each day. The experimental group as a whole played Study Hall 101 (Raley, 1999/2006) the entire period except for the few students who quickly learned the words. This translated into approximately 20 – 25 minutes of play time after logging on and logging off the computer.

The Study Hall 101 (Raley, 1999/2006) group averaged approximately 20 minutes of study time per day. Students studied an average of nine minutes per day in the control group. There was a wide range of minutes studied among the participants but the average of the group as a whole was nine minutes.

Analysis of Study

A mixed model repeated measures ANOVA was used to analyze the data. A 2 x 3 model was used. A mixed ANOVA is used when "one of the variables takes the form of repeated measures and the other variable is between-subjects – that is, independent groups of participants are identifiable" (Bell & Rowley, 2011, p. 131). In this study, repeated measures were used to look for differences in science vocabulary knowledge using test scores from different points of time in the study (pre-test, post-test, and delayed post-test) measuring science vocabulary. Time was the independent variable used in the repeated measures. Repeated measures designs are beneficial because these “eliminate some extraneous variables (such as age, IQ, and so on) and so can give us more sensitivity in the data” (Field, 2009, p. 319). Field (2009) also expresses there is power in repeated measures designs. “When the same participants are used across conditions the unsystematic variance (often called the error variance) is reduced dramatically, making it easier to detect any systematic variance” (Field, 2009, p. 342). The between-subjects analysis examined whether there were differences between the two groups of students − the experimental group using Study Hall 101 (Raley, 1999/2006) to study science vocabulary words and the control group using a study review sheet to learn science vocabulary words. SPSS was the statistical program used to analyze the data.

Using descriptive statistics (Table 2), the analysis of the pre-test showed that there is very little difference in the pre-vocabulary knowledge of the experimental group (M = 11.87) and the control group (M = 12.87). The expectation would be no significant differences would be found between the groups due to the fact that the individuals in both groups were randomly selected and assigned. This finding affirms this assumption and therefore further analysis was interpreted.

A mixed ANOVA uses the assumption of sphericity. This assumption explains that the

> relationship between scores in different treatment conditions means that an additional assumption has to be made and, put simplistically, we assume that the relationship between pairs of experimental conditions is similar (i.e. the level of

dependence between experimental conditions is roughly equal). (Field, 2009, p. 459).

Table 2

Descriptive Statistics for All Students: Science Vocabulary Knowledge- Pre-test, Post-test, and Delayed Post-test

Variable	N	Mean	Std. Deviation
Pre-test			
Experimental	55	11.87	3.657
Control	61	12.87	3.766
Total	116	12.40	3.732
Post-test			
Experimental	55	22.76	2.194
Control	61	20.11	4.428
Total	116	21.37	3.775
Delayed Post-test			
Experimental	55	21.60	3.928
Control	61	19.07	4.809
Total	116	20.27	4.575

Field (2009) continues

the accuracy of the F-test in ANOVA depends upon the assumption that scores in different conditions are independent. When repeated-measures are used this assumption is violated: scores taken under different experimental conditions are likely to be related because they come from the same participants. As such, the conventional F-test will lack accuracy. (p. 459)

When this happens a correction of the data must be made so that the F-test can be used and interpreted.

Mauchly’s Test of Sphericity is a test that SPSS uses which checks for sphericity. If Mauchly’s test statistic is significant then the assumption of sphericity has been violated. When this happens allowances must be made for the violation. In this case SPSS provides several adjustments to correct for the violation. Greenhouse-Geisser and Huynh-Feldt are two corrections that can adjust for the violation. Greenhouse-Geisser is the more conservative of the two (Field, 2009).

Analysis of the current data indicates a significance value of .0005 using Mauchly’s Test of Sphericity (Table 3). Because this value is significant then sphericity has been violated and a correction must be used. When trying to decide which correction to use, the analysis must be examined further. When examining the analysis, both the Greenhouse-Geisser correction and the Huynh-Feldt correction both indicate significance of the data, therefore Field (2009) recommends using the more conservative Greenhouse-Geisser adjustment. The following results are reported using Greenhouse-Geisser corrections.

Table 3

Mauchly’s Test of Sphericity

Within Subjects Effect	Mauchly’s W	Approx. Chi-Square	df	Sig.	Greenhouse -Geisser	Huynh-Feldt	Lower-bound
Time	.724	36.528	2	.000	.784	.800	.500

The within-subjects analysis looked for possible within-subject effects (Table 4). Taking into account the three points in time that students were assessed for science vocabulary knowledge, the F value is significant ($F = 373.64$; $p < .0005$). This analysis shows that if the individual groups are ignored − experimental and control − and the scores are examined to see where the scores increased, the results show an overall significant difference in vocabulary knowledge from pre-test to post-test and delayed post-test. This is referred to as a main effect for learning vocabulary over time. In addition, the analysis also showed that there is a significant interaction between the two independent variables groups and time of tests ($F = 16.39$; $p < .0005$).

Table 4

Tests of Within-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Time Greenhouse-Geisser	5663.144	1.567	3613.679	373.640	.000
Time * Group Greenhouse-Geisser	248.385	1.567	158.496	16.388	.000

Further analysis examined possible between-subject effects. The data indicated a significant main effect for groups. By looking at the mean scores for the two groups (Table 2) as well as the profile plot generated by SPSS (Figure 1), the data show that overall, the experimental group which used Study Hall 101 (Raley, 1999/2006) to study learned more science vocabulary words than the control group which used a study review sheet.

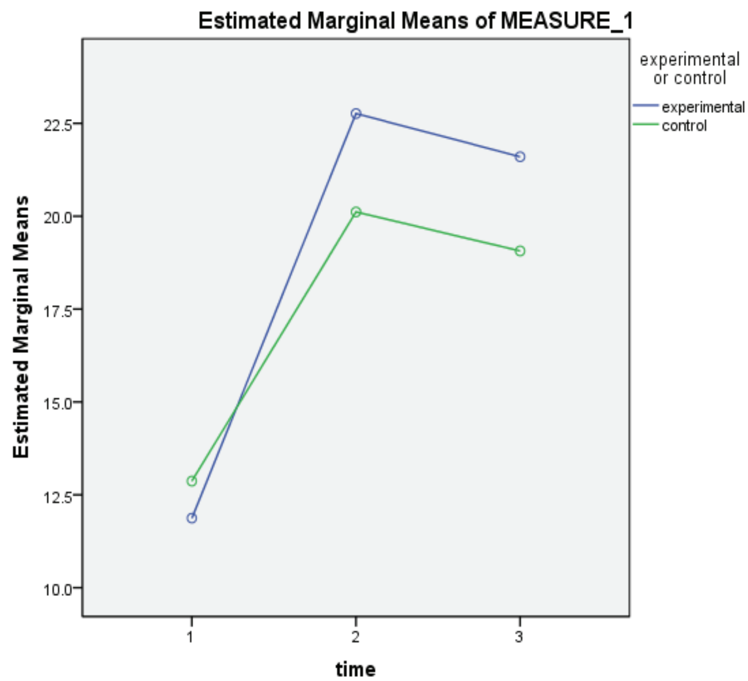

Figure 1. Interaction graph

Overall, the ANOVA analysis indicated that the two possible main effects are significant. The students in the study increased their vocabulary knowledge and students studying using Study Hall 101 (Raley, 1999/2006) learned more science vocabulary words than did students using the review sheet. The analysis also indicated that there is a significant interaction between the two independent variables.

In order to find more specific information on the interaction, additional analyses had to be performed. In looking at whether there was a significant difference in how much more the Study Hall 101 (Raley, 1999/2006) group learned, results using the specific testing times (pre, post, and delayed post), were examined by running three separate independent t-tests – one for each vocabulary test given to students. By first running and examining the data using a more complex analysis, multiple t-tests could be run without increasing Type I error.

“Parametric tests assume that the variances in experimental groups are roughly equal” (Field, 2009, p. 340). The statistic test *Levene’s Test for Equality of Variances* examines whether variances are equal. If Levene’s test is significant then equal variances cannot be assumed and a correction must be made. The SPSS analysis printout provides two rows of data − one examining equal variances assumed and one examining equal variances not assumed. The correct row must be chosen to understand the interpretation of the data.

Analysis of this study’s data using Levene’s statistic test (Table 5) indicated a non-significant value for the pre-test and a significant value for the post-test and delayed post-test. Data were interpreted using the correct Levene’s correction analysis based on these findings.

Table 5

Independent Samples Test- Levene’s Test for Equality of Variances

Variable	F	Sig.
Pre-test		
Equal variances assumed	1.167	.282
Equal variances not assumed		
Post-test		
Equal variances assumed	25.040	.000
Equal variances not assumed		
Delayed Post-test		
Equal variances assumed	9.608	.002
Equal variances not assumed		

A series of t-tests were run (Table 6) and (Table 7). The first t-test analysis examined the means of the two groups looking at pre-intervention science vocabulary knowledge. Specifically, group statistics analysis showed the two groups, experimental group (M = 11.95, SD = 3.50) and control group (M = 12.90, SD = 3.75), were similar. The analysis indicated there was no significant difference between the two groups $t(123) = 1.47$, $p = .145$). This finding would be expected based on random selection and random assignment for the subjects in the study.

The second group statistics analysis indicated Study Hall 101 (Raley, 1999/2006) students scored higher on the immediate post-test (M = 22.73, SD = 2.27) than study review students (M = 20.11, SD = 4.43). The t-test analysis showed a significant difference between the two groups $t(90.05) = 4.09$, $p = .0005$. The effect size calculations indicated a relatively large effect in the magnitude of the findings for learning science vocabulary words using Study Hall 101 (Raley, 1999/2006) ($d = .76$).

The third group statistics analysis indicated that although students' overall scores dropped slightly after 2 weeks, the delayed scores indicated that the students who studied with Study Hall 101 (Raley, 1999/2006) (M = 21.64, SD = 3.84) had a higher level of retained science vocabulary knowledge than students who studied with a study review sheet (M = 18.92, SD = 5.09). A significant difference was once again observed between the two groups $t(114.62) = 3.33$, $p = .001$. The effect size for the findings of retaining science vocabulary words over a two-week delay indicated a relatively moderate effect ($d = .58$).

Table 6

Group Statistics

Experimental or control	N	Mean	Std. Deviation
Number correct pre-test			
Experimental	62	11.95	3.504
Control	63	12.90	3.749
Number correct post-test			
Experimental	59	22.763	2.265
Control	61	20.11	4.428
Number correct delayed post-test			
Experimental	58	21.64	3.837
Control	63	18.92	5.094

Table 7

Independent Samples Test- t-test for Equality of Means

Variable	t	df	Sig. (2-tailed)
Pre-test			
Equal variances assumed	-1.468	123	.145
Equal variances not assumed	-1.469	122.675	.144
Post-test			
Equal variances assumed	4.051	118	.000
Equal variances not assumed	4.091	90.051	.000
Delayed Post-test			
Equal variances assumed	3.292	119	.001
Equal variances not assumed	3.330	114.624	.001

Question 1: Differences in Science Vocabulary Growth

Question 1 examined the difference in vocabulary growth between the experimental group which studied using Study Hall 101 (Raley, 1999/2006) and the control group which studied using a traditional study review sheet. Examining the results of an analysis of the data using a 2 x 3 repeated measures ANOVA, the results showed that both experimental and control groups showed an increase in science vocabulary knowledge from pre-test to post-test during the experiment. However, when analyzing the post-test results with a t-test comparing experimental and control groups, there was a statistically significant larger gain in knowledge by the experimental group. Students in the experimental group averaged about three more words correct on the immediate post-test than students in the control group. Specifically, the analysis showed a significant difference between the two groups $t(90.05) = 4.09$, $p < .0005$ with the experimental group who used Study Hall 101 (Raley, 1999/2006) to study science vocabulary words scoring higher on the immediate post-test than the control group. A significance level of .0005 indicated that there was only a minute possibility that these results happened by chance if, in fact, there was no actual effect from the intervention (Field, 2009). Students that used Study Hall 101 (Raley, 1999/2006) showed a statistically significant gain in science vocabulary knowledge compared to students that used a review sheet to study science vocabulary. The effect size calculations indicated a relatively large effect in the magnitude of the findings for learning science vocabulary words using (Raley, 1999/2006) ($d = 0.76$).

Question 2: Differences in Delayed Retention of Science Vocabulary Growth

Question 2 examined the difference in retention of science vocabulary between the experimental group which studied using Study Hall 101 (Raley, 1999/2006) and the control group which studied using a traditional study review sheet. Examining the results of an analysis of the data using a 2 x 3 repeated measures ANOVA, the results showed that both experimental and control groups showed a slight decrease in delayed science vocabulary knowledge from post-test to delayed post-test during the experiment. However, when analyzing the delayed post-test results using a t-test comparing experimental and control groups, there was a statistically significant larger retention of knowledge by the experimental group. Students in the experimental group retained approximately 3 more words over a two-week period following the intervention period than did students in the control group. Specifically, the t-test analysis showed a significant difference between the two groups $t(114.62) = 3.33$, $p = .001$ with the experimental group who used Study Hall 101 (Raley, 1999/2006) to study science vocabulary words scoring higher on the delayed post-test than the control group.

A significance level of .001 indicated that there was only one out of 1000 possibilities that these results happened by chance if, in fact, there was no actual effect from the intervention (Field, 2009). Students that used Study Hall 101 (Raley, 1999/2006) showed a significant retention in science vocabulary knowledge compared to students that used a review sheet to study science vocabulary. The effect size for the findings of retaining science vocabulary words over a two-week delay indicated a relatively moderate effect ($d = .58$).

Effect Size and Science Vocabulary Acquisition

Because significance does not reflect the magnitude of a study's results or the strength of the relationship that has been analyzed, it is important to report effect sizes (American Psychological Association, 2001). Cohen (1988) suggested a loose interpretation of effect sizes and how to describe the sizes. Although he cautioned in having a set way to interpret effect sizes, Cohen (1988) reported viewing $d = 0.2$ a relatively small effect size, $d = 0.5$ a relatively medium effect size, and $d = 0.8$ a relatively large effect size.

Using Cohen's *d* to calculate effect size for the findings of this study, a relatively large effect and a relatively moderate effect were calculated. The effect size calculations indicated a relatively large effect in the magnitude of the findings for learning science vocabulary words using Study Hall 101 (Raley, 1999/2006) ($d = .76$). The effect size for the findings of retaining science vocabulary words over a two-week delay indicated a relatively moderate effect ($d = .58$). The strength of this significance was slightly lower than with the immediate post-test. Regardless, this analysis indicated that there was a relatively moderate effect of the intervention in retention of information.

Although APA recommends that studies report effect sizes, few of the studies summarized in Chapter Two reported effect sizes of vocabulary learning. Nelson and Stage (2007) reported an effect size ($d = 0.18$) in a study examining vocabulary knowledge and reading comprehension using context clues. Upadhyay and DeFranco (2008) reported a partial Eta squared (Eta squared = 0.038) when examining gaining science knowledge through direct instruction and connected learning, describing it as a *weak effect*. And Dietrich (2008) reported a large effect size ($d = 0.89$) for teaching ELL first graders using explicit vocabulary instruction. In addition, Coe (2002) reported examples of effect sizes from various research studies. While different ranges of effect sizes were reported, most of the academic effect sizes were in the small to moderate range: Students' test performance in reading (0.30), Achievement (all studies) (0.24), Targeted interventions for at-risk students (0.63), Students' test performance in math (0.32), Inquiry-based vs. traditional science curriculum (0.30), and Individualized instruction for increased achievement (0.10). The effect sizes from this study (science vocabulary growth, $d = 0.76$; science vocabulary retention, $d = 0 .58$) are considerably larger as compared to most of these other academic effect findings.

In addition, when examining interventions, it is important to examine the effect size of each intervention individually with an understanding of how that particular effect size can represent not only a statistical significance but a practical significance depending on the area of the discipline. According to Coe (2002) it is important to interpret this based on relative *costs and benefits* of the intervention. For example,

> in education, if it could be shown that making a small and inexpensive change would raise academic achievement by an effect size of even as little as 0.1, then this could be a very significant improvement, particularly if the improvement applied uniformly to all students, and even more so if the effect were cumulative over time. (Coe, 2002, p. 104)

He continued, "Even Cohen's 'small' effect of 0.2 would produce an increase from 50% to 58% − a difference that most schools would probably categorize as quite substantial" (Coe, 2002, p. 7).

An intervention with a small effect size in education could possibly produce enough gains to increase learning which could translate into improved grades and reductions in failures, or increased knowledge leading to enhanced understanding.

Therefore, an intervention with relatively large effect sizes, like the one of this study, shows an even greater magnitude in the results of the learning that occurs when using Study Hall 101 (Raley, 1999/2006). Additionally important, however, is the practical significance of increasing science vocabulary in a game format that shows significant differences in learning with relatively little cost and increased benefit. As discussed earlier, an effect size should be analyzed within the scope of the field and in comparison with other studies of comparable findings. For instance, if an increase in retention of vocabulary can promote understanding (Nagy et al., 1987) an intervention with the magnitude of these findings that increases vocabulary knowledge could possibly produce enough actual gains to help students increase scores and be more successful on semester tests, state tests, or end-of-course exams.

CHAPTER FIVE

Discussion

The purpose of this study was to examine if there was a significant difference in learning science vocabulary words when using computer-assisted learning compared to a traditional vocabulary review sheet. In addition, delayed post-test scores were examined to see if there was a significant difference in retention between the two methods of learning. First, a summary of the sample and the intervention used in the study is discussed. Secondly, a summary of the results and each question of the study is restated and discussed. Third, previous research and theory and how each relates to the current study are discussed. Fourth, limitations of the study are cited. Fifth, recommendations for further research are explored. Lastly, conclusions and implications are discussed.

Summary of Sample

The obtained sample of this study consisted of 125 fourth and fifth grade students from a suburban intermediate school in central Texas. Specifically, the intermediate school, which houses fourth, fifth, and sixth grade students, has 543 students. Fourth, fifth, and sixth grades have 180, 180, and 183 students each, respectively. Demographics of this school were obtained from the Texas Education Agency website (2010-2011 school year). The demographics of the school consist of 79.8% Caucasian, 13.4% Hispanic, 4.3% African American, 0.4% Native American, 0.2% Asian, 0.2% Pacific Islander, and 1.7% Two or more races. Of the school's population, 31.9% are economically disadvantaged, 0.8% are identified as Limited English Proficient (LEP), and 26.7% are identified as At-Risk. Students with disciplinary placement include 0.8% of the population. Special populations include gifted and talented (15.9%) and special education (9.1%). As reported in TEA's Adequate Yearly Progress (AYP) District Data Table (2010-2011), China Spring had a 97.2% graduation rate. TEA awarded this district a Recognized rating and reported that the district met AYP criteria. The school specifically was awarded an exemplary rating by TEA.

Students were randomly chosen to participate in the study from students that returned signed consent forms and randomly assigned to either experimental or control group. There were 62 students in the experimental group and 63 students in the control group. The school district agreed to let students be a part of the study during special time in their schedules. Therefore a true experimental design could be used and no core class time instruction was missed.

Summary of Intervention

Twenty-four science vocabulary words were studied by both the experimental and control groups. The experimental group studied using computer-assisted learning and the control group studied using a traditional review sheet. Each group had the opportunity to study the words for a total of 200 minutes (five 40-minute class periods) over a two-week period. On the first day of the study, the researcher introduced the interventions to both groups. The researcher also used 10 minutes on the first day of the study to introduce Study Hall 101 (Raley, 1999/2006), a computer game-based intervention, to the students and to explain how to play. None of the students had difficulty with game play. Both groups in the study had a teacher monitoring the classroom during the intervention. The teachers were there to answer technical questions and to maintain a quiet environment conducive to studying. The teachers were instructed not to redirect off task behavior unless it was bothersome to other students. The researcher was present at the school for the first two days of the intervention in case there were any technology difficulties in the computer lab or any other questions that had to do with implementation. After the first two days the researcher periodically visited both conditions and monitored the studying of both groups. The intervention coordinator at the school was available for questions or problem solving during the study as well. The intervention coordinator was the intermediary between the school and the researcher so that students' data could remain anonymous throughout the study.

A 24-item assessment, *Test of Science Vocabulary*, created by Rollins (2011) was used in the study. The assessment was created by the researcher due to the fact that no already published instrument could be found that measured multiple levels of science vocabulary and their definitions. A pilot test was conducted to find the most appropriate words to be used for the assessment. Words for the pilot were taken from a combination of an eighth-grade TAKS study guide for science vocabulary created by an education service center as well as upper level words taken from a Marzano and Pickering (2005) word list. The words chosen from the Marzano and Pickering (2005) list were upper level grade (9-12) science vocabulary words. A 100-item pilot test was given to a group of fifth grade students the previous year so that an item analysis could be conducted to see which words would be best to be used in the testing instrument. After tests were scored an item-analysis was performed using SPSS. An initial reliability of .883 was established using Cronbach's Alpha with all 100 items of the pilot. The 24 words with the highest discrimination values were then chosen. The range of discrimination was between .635 and .360. Reliability was performed again using SPSS on the 24 chosen words with a Cronbach's Alpha of .882. Because this represented an acceptable alpha for an achievement test, the *Test of Science Vocabulary* (Rollins, 2011) was used as the instrument to assess vocabulary knowledge in this study. Both experimental and control groups took a pre-test using the *Test of Science Vocabulary* (Rollins, 2011) in order to assess pre-intervention knowledge and to look for differences between the two groups. After the intervention, both groups were given an immediate post-test as well as a delayed post-test two weeks later to look at science vocabulary growth and retention of science vocabulary words learned. The *Test of Science Vocabulary* was given for the post-test and the delayed post-test.

Summary of Results

A mixed repeated measures ANOVA was used to analyze the data. A 2 x 3 model was used because there was a between-subjects group with two levels − experimental group and control group, and three repeated measures examining science vocabulary growth and retention. The three measures used were pre-test, post-test after a two-week intervention, and delayed post-test given two weeks later. Descriptive statistics showed there was no difference between pre-test scores of the experimental and control groups. This suggested that the subjects used in the study were similar and were therefore acceptable to use in further analysis. This would be expected when using a randomized experimental design as was used in this study

The within-subjects analysis looked for possible within-subject effects. Initial quantitative analysis of the data using repeated measures indicated that there was a main effect for learning vocabulary over time. An overall significant difference (F = 373.64;

$p < .0005$) in vocabulary knowledge from pre-test to post-test and delayed post-test was indicated. Analysis also showed that there was a significant interaction between the two independent variables groups and time of tests ($F = 16.388$; $p < .0005$). Further analysis indicated a significant main effect for groups. By looking at the mean scores for the two groups as well as the profile plot generated by SPSS, the data showed that overall, the experimental group which used Study Hall 101 (Raley, 1999/2006) to study, learned more science vocabulary words than the control group which used a study review sheet.

Overall, the mixed model repeated measures ANOVA analysis indicated that the two possible main effects were significant. The students in the study increased their vocabulary knowledge and students studying using Study Hall 101 (Raley, 1999/2006) learned more science vocabulary words than did students using the review sheet.

In order to find more specific information on the interaction, three separate independent t-tests were run − one for each vocabulary test given to students. The first t-test analysis examined the means of the two groups looking at pre-intervention science vocabulary knowledge. Specifically, analysis showed the two groups, experimental group ($M = 11.95$, $SD = 3.50$) and control group ($M = 12.90$, $SD = 3.75$), had similar means. The analysis indicated there was no significant difference between the two groups $t(123) = 1.47$, $p = .145$). This finding would be expected based on random selection and random assignment for the subjects in the study.

The second t-test analysis indicated Study Hall 101 (Raley, 1999/2006) students scored higher on the immediate post-test ($M = 22.73$, $SD = 2.27$) than study review students ($M = 20.11$, $SD = 4.43$). The analysis showed a significant difference between the two groups $t(90.05) = 4.09$, $p = .0005$. Students who studied science vocabulary words using Study Hall 101 (Raley, 1999/2006) learned more words after a two-week intervention time period. The effect size of the intervention as it related to knowledge learned as reported by Cohen's *d* represented a relatively large effect size ($d = 0.76$).

The third t-test analysis indicated that although students' overall scores dropped slightly after two weeks, the delayed scores indicated that the students who studied with Study Hall 101 (Raley, 1999/2006) (M = 21.64, SD = 3.84) still had a higher level of retained science vocabulary knowledge than students who studied with a study review sheet (M = 18.92, SD = 5.09). A significant difference was once again observed between the two groups $t(114.62) = 3.33$, $p = .001$. Students who studied science vocabulary words using Study Hall 101 (Raley, 1999/2006), retained more words after a two-week delayed period of time. The effect size of the intervention as it related to retained knowledge as reported by Cohen's *d* represented a relatively moderate effect size ($d = 0.58$).

Question 1

Is there a difference in the growth of science vocabulary between students who participate in a computerized vocabulary program versus those who participate in a traditional vocabulary review sheet?

A mixed repeated measures 2 x 3 ANOVA and t-tests were used to analyze the data. Both groups showed an increase in science vocabulary knowledge. However, after five days of studying using Study Hall 101 (Raley, 1999/2006), the experimental group learned statistically significant more science words and definitions than did the control group that used a review sheet to study. Significance was found at the .0005 level. Students who studied science vocabulary words using Study Hall 101 (Raley, 1999/2006) learned more words at a statistically significant level than students who studied the same words using a traditional vocabulary review sheet.

While showing a significant difference between groups is important, it does not reflect the strength of the intervention. Examining the effect size of a study not only allows individuals to better understand the strength of the results but it enables individuals to compare studies without the sample size factoring into the analysis (Becker, 2000). The effect size looking at Study Hall 101 (Raley, 1999/2006) as an intervention to increase science vocabulary knowledge was computed using Cohen's *d*. The effect size of the intervention as it applied to immediate recall of learned science vocabulary words ($d = 0.76$) represented a relatively large effect in learning. A large effect size indicates that the strength of the intervention is strong and the intervention would be beneficial in a similar setting. This is especially significant due to the fact that Study Hall 101 (Raley, 1999/2006) is relatively inexpensive and lets students study independently allowing the teacher more time to work one-on-one with other individual students.

The practical significance of a science vocabulary intervention that increases students' retention of science vocabulary and knowledge may have positive educational implications in the classroom. As discussed earlier, vocabulary knowledge increases prior knowledge (Moje, 2008) which leads to better understanding and increased reading abilities (Nagy et al., 1987). Increasing science vocabulary knowledge could lead to further understanding and comprehension (Pressley et al., 2007).

Question 2

Is there a difference in science vocabulary retention between students who participate in a computerized vocabulary program versus those who participate in a traditional vocabulary review sheet?

As with the previous question, a mixed repeated measures 2 x 3 ANOVA and a series of t-tests were used to analyze the data. Descriptive statistics indicated there was no difference between pre-test scores of the experimental and control groups. This would be expected when using a randomized experimental design. This suggested that the subjects used in the study were similar and were therefore acceptable to use in further analysis.

Quantitative data analysis indicated that both groups showed an increase in retention of science vocabulary knowledge. However, after five days of studying using Study Hall 101 (Raley, 1999/2006), the analysis indicated that the experimental group retained statistically significant more science words and definitions after a two-week delay than did the control group that used a review sheet to study. Significance was found at the .001 level. Students who studied science vocabulary words using Study Hall 101 (Raley, 1999/2006) were able to retain a greater amount of words at a statistically significant level than students who studied the same words using a traditional vocabulary review sheet.

As discussed earlier the effect size of using Study Hall 101 (Raley, 1999/2006) to study science vocabulary words was computed using Cohen's *d*. Cohen's *d* calculations indicated a relatively moderate effect size for delayed retention (0.58). While this effect size may be interpreted generally as moderate, the practical significance of a science vocabulary intervention that increases students' long term retention of science vocabulary and knowledge may have even larger positive educational implications in the classroom. Because students' ability to learn information impacts success in school and a large number of students, even at the high school and college level, do not know how to study (Mastropieri & Scruggs, 2007), an intervention such as Study Hall 101 (Raley, 1999/2006) that has a moderate effect size for retained information may fill the gap in an area where there is great need. Long-term retention of information is especially beneficial for school related success with things such as chapter tests, unit tests, semester tests, and end-of-course exams.

Previous Research and Theory

Science knowledge is a very important part of our society and our economy. Science knowledge impacts us every day in understanding the world around us. It also supports a discipline that leads to many important jobs and careers. However, today's students in the U.S. are not performing as well as in science as students in other countries.

It is important that the U.S., in maintaining its competitive position with the rest of the world, focus on science knowledge and literacy and find ways to increase learning in the sciences. In order to increase science knowledge schools must focus on the language of the discipline. Vocabulary development is important across all disciplines.

Language abilities directly affect academic success (McGuinness, 2005). Vocabulary knowledge specifically leads to being a better reader (Constantinescu, 2007), furthers understanding (de Villiers & Johnson, 2007), and increases knowledge of content (Shook et al. 2011). Science vocabulary knowledge also has significant benefits.

Science vocabulary knowledge prevents misunderstanding based on the wrong assumptions from context clues (Hiebert & Cervetti, 2011), allows decoding and understanding of complex science texts (Bravo et al., 2007), and increases interest and produces better attitudes towards the sciences (Mamlok-Naaman, 2011).

While research has shown that science vocabulary knowledge is important, not many research studies have explored the best ways to increase science vocabulary. A review of the literature found many more studies focused on general vocabulary knowledge (Kilickaya & Krajka, 2010; Nelson & Stage, 2007; Spiri, 2008) rather than academic vocabulary knowledge.

Several of the *general* vocabulary studies reviewed for this study looked at the use of direct instruction, context clues, and technology to increase vocabulary knowledge. While both direct instruction studies (Dietrich, 2008; Pany et al., 1982) found different results in terms of statistical significant differences, both found that multiple exposures and review led to increased vocabulary. Studies examining vocabulary acquisition through context clues found mixed results. However, those studies that did find that context clues increased vocabulary knowledge found small gains (Nagy et al., 1987; Nelson & Stage, 2007). Several studies examined the benefits of using technology to learn vocabulary. The results of the studies using technology were the most consistent in amount of vocabulary learned and statistical significance of the results (Ma & Kelly, 2006; Kilickaya & Krajka, 2010; Spiri, 2008). Overall, learning vocabulary using technology appeared to be the most effective.

In looking at the studies that focused on learning *academic* vocabulary, the focus was on direct instruction and computer-assisted learning. Results from these studies looking at learning academic vocabulary through direct instruction found that direct instruction was a successful intervention aiding students in learning academic vocabulary. However, the type of direct instruction used in each study was very different. Two focused the direct instruction by using graphic organizers (Horn & Feng, 2012; McAdams, 2012) and the third had many different variables as a part of the direct instruction (D'Alesio et al., 2007). Of these, only McAdams (2012) focused on science vocabulary.

Only two studies that used computer-assisted learning focused on specific academic vocabulary. Salsbury (2006) focused on geography and Muehrer et al. (2012) focused on science. The results of these studies found that both computer-assisted learning interventions showed a statistically significant difference between pre- and post-tests and between intervention and control. In addition, both researchers felt that motivation of the students because of the game play on the computer played a factor in the success of the learning.

Principles of learning theory provide a foundation on which to examine best practice for learning science vocabulary words. Instructional design, based on behaviorism, combines the successful components of the previous research. Several of the same components that support general and academic vocabulary development can also support the success of learning science vocabulary.

Direct instruction, which several of the studies in the literature review incorporated, stresses that learning occurs when a behavior is changed. Behavioral theory also posits that learning occurs through repetition and practice leading to automaticity. Reinforcement theory explains that change occurs through reinforcers—

either pleasing or unpleasant. Behaviors that are reinforced causing a pleasing feeling are more often to be repeated. Behaviorists also believe that anyone can learn if the information is broken down into small enough units and presented in a way that promotes mastery.

Examining the studies previously discussed, in light of behaviorism and instructional design, there were several common components which led to vocabulary success. These components are also an integral part of Study Hall 101 (Raley, 1999/2006). For example, Study Hall 101 (Raley, 1999/2006) uses technology which shows to be very effective in learning vocabulary. Study Hall 101 (Raley, 1999/2006) also uses repetition and practice for multiple exposures and review through game play to lead to automaticity. The words to be learned are broken down into smaller groups with immediate feedback to promote learning. The game itself is very rewarding in that it is an interactive computer game that uses visual and auditory feedback to reinforce learning.

While the American Psychological Association (2001) recommends that researchers now report effect size in order to help others better understand the magnitude of their findings, few of the studies previously discussed in this study examining vocabulary acquisition reported effect sizes. Only three out of the 14 studies discussed in this study reported effect sizes. Of the studies that did report effect size two reported a small effect size (Nelson & Strange, 2007; $d = 0.18$; Upadhyay & DeFranco, 2008; Eta squared = 0.038), and one reported a large effect size (Dietrich, 2008; $d = 0.89$). And, of these three, only one examined learning science information (Upadhyay & DeFranco, 2008). Additional studies and their effect sizes were reported by Coe (2002). From the group of studies that Coe (2002) listed, of those that focused on some aspect of academic learning, the effect size usually fell within the small effect size range. Only one study reported was specifically science related and it had a relatively small effect size.

Not only does this study investigating Study Hall 101 (Raley, 1999/2006) report effect sizes for both science vocabulary knowledge gained (0.76) and for science vocabulary retention (0.58), which very few other studies reported, these effect scores represent both a strong and moderate strength associated with learning science vocabulary. The magnitude for this intervention suggests that there is a strong likelihood that using Study Hall 101 (Raley, 1999/2006) would produce successful results in helping fourth and fifth grade students learn science vocabulary words. And when students are more successful in their learning they are more likely to be able to learn better in school even though the class or teacher has not changed (Bloom, 1984).

Results of this study indicate that Study Hall 101 (Raley, 1999/2006) is a learning intervention that provides both statistical and practical significance. Analysis of the data when fourth and fifth grade students played Study Hall 101 (Raley, 1999/2006) showed that they learned more science vocabulary words and also retained more science vocabulary words than the group that studied using the study review sheet.

Limitations

As with all studies there were limitations to the study that should be taken into consideration. First, the study focused only on fourth and fifth grade students in a suburban setting with a predominantly middle class SES. Because of this focus, the results of the study cannot be generalized to different grade levels or to different types of school settings.

Secondly, this study explored whether there were differences between control and experimental groups regardless of strengths and/or weaknesses of the students within the groups. Therefore the results of this study cannot be generalized to different populations of students without further analysis of specific groups of students.

Thirdly, this study focused on 24 science vocabulary words. This may be a low number compared to the actual number of vocabulary words that must be learned in any given chapter in science. At times in the classroom there are many more words that must be learned. Learning more words within the study might have allowed a greater understanding of how computer-assisted learning impacts learning of larger sets of information.

Finally, conducting a study with students in a school rather than in a lab where there can be more control of variables may have impacted the results somewhat. Having to alter the amount of days that students studied and having to allow choice for amount of study time for the control group once the study began created a less than desired study design. Once the change was made, students in the control group tallied how many minutes they studied each of the four days left in the study. The control group overall averaged nine minutes of study time each day over the four days left in the study. The experimental group averaged approximately 20 minutes of study time each day. Although these numbers show a discrepancy in the amount of time each group spent studying, the practical application represents how students typically study. Students study more when they are engaged with the information and technology is designed to engage students. Based on the unforeseen complication of students' morale the researcher felt it was better to alter the design that to abort the study. However, the researcher felt it was possible to be flexible without significantly impacting the study in a negative way. Time engaged in study and motivation may therefore be important variables to study along with the specific intervention.

Directions for Future Research

The importance of vocabulary instruction and knowledge has been well established. The benefits are many. Vocabulary knowledge impacts understanding at the most basic level (Marzano & Pickering, 2005), helps students become more proficient readers (Bravo et al., 2007), and provides important background knowledge. Background knowledge increases knowledge through understanding complex texts (Moje, 2008), the ability to integrate new information (Nagy et al., 1987), being able to connect new words and knowledge which increases understanding (de Villiers & Johnson, 2007), and confidence in knowledge leading to improved achievement and increased motivation (Mamlok-Naaman, 2011). There is justification within the literature on finding ways to teach unknown vocabulary words (Pressley et al., 2007).

It has also been established that science vocabulary is important for success. Specifically, science vocabulary development is critical for understanding science concepts (Pressley et al., 2007), understanding science texts (Bravo et al., 2007), exposing students to words not found in everyday language (Hiebert & Cervetti, 2011), and increasing science self-efficacy (Tsai et al., 2011).

Because of the importance of science vocabulary in understanding and in student success, the following areas will be important in expanding the results of this study:

1. It will be important to explore additional ways that computer-assisted programs can increase science vocabulary knowledge. Because research supports both

the importance of science vocabulary and the benefits of computer-assisted learning, more research should be conducted merging the two. While there is a plethora of research exploring best practices of vocabulary development in reading, there is comparatively very little research in increasing science vocabulary. Out of the literature review for this study, only five studies that focused on increasing science vocabulary were comparable to using Study Hall 101 (Raley, 1999/2006). Of the five studies that targeted science vocabulary three looked at other words along with science (D'Alesio et al., 2007; McAdams, 2012; Nagy et al., 1987). Only two studies (Muehrer et al., 2012; Upadhyay & DeFranco, 2008) focused specifically on science vocabulary. In particular, research exploring how computer-assisted learning can increase science vocabulary is all but non-existent. Of the studies focusing specifically on science vocabulary only Muehrer et al. (2012) used computer-assisted learning to teach science vocabulary words.

2. Replicating this study or similar studies using computer-assisted learning to increase science vocabulary with other grade levels would increase the generalizability of the research. It would be beneficial to discover if high school students increase their science vocabulary knowledge using Study Hall 101 (Raley, 1999/2006) as did the intermediate students in this study. Practical significance would also be important to explore because a large number of students, even at the high school and college level, do not know how to study (Mastropieri & Scruggs, 2007). Of the studies in the literature review that focused generally on increasing science vocabulary, three focused on elementary/middle school grades (D'Alesio et al., 2007; McAdams, 2012; Nagy et al., 1987). Only one (Muehrer et al., 2012) looked at high school students increasing science

vocabulary words. The study by Muehrer et al. (2012) was also the only study that examined science vocabulary acquisition using computer-assisted learning.

3. It would be beneficial to find out if studying with Study Hall 101 (Raley, 1999/2006) leads to significantly increased knowledge and retention of science vocabulary in special populations of students including but not limited to: male/female, learning disabled, gifted and talented, identified 504, at-risk, low SES, ELL, and/or the slow learner. Students in special populations sometimes have special learning difficulties. Students that have difficulties in learning and/or difficulties with behavior often have a difficult time remembering academic content (Scruggs & Mastropieri, 2000). Students with disabilities often face challenges with content. Many times students with emotional and/or behavioral problems receive less academic instruction than their peers which makes them particularly vulnerable to continued academic failure (Alber-Morgan, Ramp, Anderson, & Martin, 2007). In addition, inclusion education, currently a key policy, will require more and more learners with difficulties to remain in the regular education classroom (Lindsay, 2007). Even gifted students can benefit from special content instruction such as vocabulary development (Goss, 2004).

4. Future studies should focus on comparing other computer-assisted learning tools in learning science vocabulary with other types of research-based strategies. Examining the magnitude of both will add to the literature helping teachers and students know which study techniques show the greatest promise.

> By placing the emphasis on the most important aspect of an intervention - the size of the effect - rather than its statistical significance (which conflates effect size and sample size), it promotes a more scientific approach to the accumulation of knowledge. For these reasons, effect size is an important tool in reporting and interpreting effectiveness. (Coe, 2002, para. 2)

Reporting study strategies with strong effect sizes would add to the research base of successful learning techniques (DeVry & Brown, 2000) and focusing specifically on science vocabulary strategies using computer-assisted learning would add to an area that is lacking in research. Time engaged and motivation may also be important variables to explore.

Conclusion and Implications

Previous research explained the importance of science in today's world. Science is important not only to individuals in understanding the world around them but to the success of the nation in terms of being competitive and innovative to further enrich individual lives. In order for this to happen, individuals must be ready to enter STEM fields with knowledge and expertise for growth. However, data have shown that the U.S. is behind in preparing students with a strong foundation in science.

One aspect that is important to learning information in any academic field is knowledge of the discipline of the language. Not only does being fluent in the specific language of a discipline allow in-depth discussion, it also allows individuals to read and comprehend the concepts specific to each discipline.

Research previously summarized has shown that direct instruction is a beneficial way to teach vocabulary. However studies that have investigated how to increase vocabulary knowledge using direct instruction have included multiple variables (D'Alesio et al., 2007; Pany et al., 1982). Including multiple variables within the design of the study makes it difficult to decide which of the variables were most important in increasing knowledge. This study examined the use of a single intervention − Study Hall 101 (Raley, 1999/2006) − to examine whether direct instruction was beneficial in learning vocabulary. In this way, the researcher was able to determine if this variable influenced growth in science vocabulary.

Knowledge of science vocabulary is critical for being successful in school and in the field. While there have been studies over the years that have investigated best teaching practices and strategies for learning vocabulary, not many studies have looked specifically at science. And, most of the studies cited which reported significant findings did not report the magnitude of the findings using effect size. In the studies mentioned in previous chapters only three reported effects size: Dietrich (2008) (0.89), Nelson & Stage (2007) (0.18), and Upadhyay & DeFranco (2008) (partial eta squared 0.038). Only Upadhyay & DeFranco (2008) examined science knowledge and they reported a weak effect size. This study, looking at Study Hall 101 (Raley, 1999/2006), included effect sizes of the intervention in order to add to the literature not only the significance but also the magnitude of the findings. While most vocabulary instruction often only has small or modest effects (Pressley et al., 2007) Study Hall 101 (Raley, 1999/2006) had a large effect size for science vocabulary knowledge ($d = 0.76$) and a moderate effect size for retained science vocabulary knowledge ($d = 0.58$).

While the benefits of computer-assisted instruction (CAI) are many, few studies reviewed focused on increasing science vocabulary. The majority of CAI learning focused on general vocabulary acquisition (Kilickaya & Krajka, 2010; Ma & Kelly, 2006; Spiri, 2008). Only Salsbury (2006) and Muehrer et al. (2012) addressed learning academic-specific vocabulary. And, only Muehrer et al. (2012) focused on science vocabulary and knowledge which showed a statistically significant increase on quiz scores after game play.

Based on these findings and due to a lack of research in the literature on acquiring science vocabulary, this study examined an intervention to see if it increased science vocabulary. The study looked specifically at computer-assisted instruction to see if there was a significant difference in learning science vocabulary when compared to a more traditional review sheet. The results of this research were strengthened because a true experimental design was used.

The use of Study Hall 101 (Raley, 1999/2006) showed statistically significant results in both science vocabulary knowledge and retained science vocabulary knowledge. Not only were there significant differences, but effect sizes of large and moderate effects were indicated. In addition, "using technology to learn incorporates motivation and engages learners" (Moon, Jahng, & Kim, 2011, p. 11). This was evidenced in the amount of study time differences between the experimental and control groups. The results of this study will add to the literature on science vocabulary acquisition and help to identify ways to assist students in learning more in the world of science.

Twenty-five years ago, Johnson et al. (1987), wrote, "an efficient, computer-assisted method of vocabulary instruction could provide an additional tool for teaching vocabulary" (p. 211). This study corroborates Johnson's (1987) conclusion. Educators need to further explore the findings of this study examining this intervention with students across grade levels and from diverse populations, which may benefit students' understanding of the STEM areas.

APPENDIX

APPENDIX

Test of Science Vocabulary- pre-test

Code Number _________

1. A push or pull in a direction:
   a) motion
   b) force
   c) acceleration
   d) energy

2. After something has been stretched or compressed, the tendency of it to return to its original shape:
   a) advection
   b) elasticity
   c) chemical bond
   d) energy

3. In a wave- its lowest point:
   a) media/medium
   b) amplitude
   c) trough
   d) crest

4. Energy that is stored:
   a) kinetic energy
   b) potential energy
   c) radiant energy
   d) electrical energy

5. Either positive or negative electrical energy:
   a) catalyst
   b) charges
   c) chemical change
   d) physical change

6. The number of waves passing a point in a given amount of time:
   a) wavelength
   b) amplitude
   c) frequency
   d) medium

7. When temperature is perceived as energy:
   a) radiant energy
   b) heat energy
   c) kinetic energy
   d) electrical energy

8. A change in a substance that creates a new substance with different properties from the original substance:
   a) physical change
   b) chemical change
   c) elements
   d) compounds

9. When there are the same number of protons but a different number of neutrons:
   a) charge
   b) catalyst
   c) isotope
   d) ion

10. The linking of atoms by an electrical force:
   a) unbalanced forces
   b) motion
   c) atom
   d) chemical bond

11. The product of living cells described as a catalytic protein:
    a) energy
    b) frequency
    c) enzyme
    d) trough

12. When energy changes in form:
    a) friction
    b) acceleration
    c) unbalanced force
    d) transformation

13. The energy an object has because of its motion:
    a) potential energy
    b) heat energy
    c) electrical energy
    d) kinetic energy

14. When in motion, the force that opposes it:
    a) unbalanced force
    b) energy
    c) transformation
    d) friction

15. The number of protons in the nucleus of an atom:
    a) atomic number
    b) atomic mass
    c) charge
    d) electrons

16. The distance between two consecutive crests or troughs of a wave:
    a) wavelength
    b) frequency
    c) amplitude
    d) sound

17. A change in a substance that does not affect the substance itself:
    a) chemical change
    b) physical change
    c) element
    d) compound

18. When electromagnetic waves transmit energy:
    a) radiant energy
    b) kinetic energy
    c) heat energy
    d) potential energy

19. The horizontal transfer of heat or other atmospheric properties:
    a) chemical bond
    b) advection
    c) acceleration
    d) wavelength

20. The practical use of biological processes:
    a) pH
    b) chemical technology
    c) physical technology
    d) biotechnology

21. A wave can travel through this substance:
    a) sound
    b) frequency
    c) media/medium
    d) trough

22. When heat is transferred through a fluid caused by molecular motion:
    a) friction
    b) acceleration
    c) transformation
    d) convection

23. A rippling motion traveling through a medium that transmits energy:

a) crest
b) wave
c) trough
d) wavelength

24. When the application of electricity causes energy:

a) radiant energy
b) electrical energy
c) kinetic energy
d) heat energy

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