

INQUIRY-BASED INSTRUCTIONAL STRATEGIES AND
SCIENCE CONTENT VOCABULARY

by

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in

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DEDICATION

Thank you to my friends and family for supporting me through this process. I would like to acknowledge my students for always inspiring me and pushing me to become a better educator and do right by them. Special thanks to Dr. John Graves, Dr. Angela Sower, and the MSSE program (Montana State University, Bozeman, MT).

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ABSTRACT

Due to the sophisticated academic vocabulary in science, students need help in learning and processing academic vocabulary and language to become independent science learners. The purpose of this study was to investigate which inquiry-based instructional strategies will effectively improve student acquisition of science content vocabulary. This action research-based classroom project was conducted at Heritage High School in Littleton, Colorado.

Treatment was implemented in three freshman level physical science classes ($N=87$) during the months of January, February, and March 2017. Content-specific vocabulary terms were taught using traditional direct instruction and compared to vocabulary instruction using the inquiry-based strategies 5E Learning Cycle and gamification.

Comparison of vocabulary pre- and post-assessments has shown that all three instructional strategies improved student vocabulary acquisition ($p = 0.00$), however there was not a significant difference between the three instructional strategies ($p = 0.49$). The 5E Learning Cycle had the highest post-test mean score, highest average normalized gains, and had the greatest decrease in standard deviation between the pre-and post-test indicating it was likely more effective than direct instruction and gamification instructional strategies.

Student responses on the Student Input Survey and post-treatment interviews showed that students enjoyed the 5E Learning Cycle and gamification instructional strategies and felt that these strategies improved their motivation, engagement, and learning of content vocabulary more than direct instruction.

INTRODUCTION AND BACKGROUND

Among students, science is commonly thought of as a challenging subject. I believe one reason that students find learning science difficult is that it introduces a significant amount of content specific academic language that many students have not been exposed to previously. In many science content areas, the vocabulary is very closely related to the concepts, and vocabulary acquisition is fundamental to students' understanding of science content. If a student does not have a strong grasp of the vocabulary, then they likely do not have a strong grasp of the related science concepts. Additionally, strong knowledge of content vocabulary is required for students to engage in academic conversations, increase reading comprehension and fluency of science texts, and improve students' scientific writing.

Throughout my teaching experience, I have observed that students have poor acquisition and retention of content related vocabulary. My colleagues and I tend to use a traditional method of teaching vocabulary which involves memorizing the word and its definition using flash cards or vocabulary logs. The assumption is that students are studying vocabulary at home with occasional vocabulary reviews and assessments given in class. However, based on consistently low quiz and test scores, this method does not seem to work effectively and it does not appear that students utilize these study tools at home.

This study was conducted at Heritage High School located in Littleton, Colorado. Heritage High School is a public comprehensive neighborhood high school that has earned the national Blue Ribbon of Excellence designation and has a graduation rate of

91%. The school is in a suburban setting and serves approximately 1,700 students where 14% of students qualify for free and reduced lunch. Approximately 79% of students are Caucasian, 13% of students are Hispanic, 3% of students identify as multiracial, and 2% of students are Asian. Heritage has a 1:1 male to female ratio (Littleton Public Schools, 2016).

This action research-based classroom project was designed to determine whether embedding vocabulary instruction within my curriculum would improve student understanding of science content. Specifically, my focus question was: *will inquiry-based instructional strategies improve student acquisition of science content vocabulary? If so, which methods are most effective?*

CONCEPTUAL FRAMEWORK

The challenge of science at the secondary level is that students must learn highly specialized terminology before they can fully understand the subject (Misulis, 2011). Vocabulary development has been shown to raise self-esteem, improve capacity to learn, and increase comprehension (Manzo, Manzo, & Thomas, 2006). Efforts to help students understand science cannot ignore the need for students to also understand the words used to write and talk about science (Snow, 2010).

Two dominant types of vocabulary have been identified: domain-specific academic vocabulary and general academic vocabulary. Domain-specific academic vocabulary is defined as content-specific terms and expressions found in content area textbooks and other technical writing. The term general academic vocabulary refers to words that appear across multiple disciplines and can therefore have different meanings (Bauman & Graves, 2010). Science content vocabulary can be particularly problematic

for students since many vocabulary words such as work, table, wave, hypothesis, and analysis have precise scientific meanings that differ from their everyday use and can vary across scientific disciplines (Wessels, 2013).

A classifying system was developed to help teachers in selecting academic vocabulary for instruction. While the original system's focus was on mathematics vocabulary, the system can be applied to other content areas. It was recommended teachers break vocabulary terms into one of five categories: domain-specific academic words that are low frequency and content specific, general academic vocabulary that appear frequently and across content areas, descriptive literary vocabulary, metalanguage terms that are used to describe, discuss, or analyze, and finally symbols that represent objects and processes (Baumann & Graves, 2010).

After identifying and selecting what academic vocabulary to teach, the goal is then to know how to effectively teach it (Baumann & Graves, 2010). The traditional method of vocabulary instruction such as looking up words in a dictionary and writing the definitions has been an ineffective approach to teaching vocabulary. Several recommendations were made on how teachers can integrate vocabulary instruction into their curriculum. Examples include engaging students in activities that will increase their oral competency with content vocabulary, activating prior knowledge and supporting students in connecting it to new concepts, teaching students how to use context to infer word meanings of unfamiliar vocabulary, creating dictionaries of common Greek and Latin root words, using direct instruction with emphasis on word meaning and structure, and teaching fewer words more effectively (Bromley, 2007).

To increase students' vocabulary acquisition, several strategies were suggested that teachers can easily use to supplement their curriculum. Examples include having students focus on the structural features of words, determining meaning through context, providing opportunities to use vocabulary in lessons, brainstorming, graphic organizers, categorizing activities, and literal-level vocabulary activities (Misulis, 2011). The effectiveness of using flash cards coupled with a helper word or mnemonic device in improving vocabulary acquisition was studied for students with learning disabilities. The students were given five minutes each day to study vocabulary with their flashcards and were expected to monitor their progress by graphing the number of correct words each day. Pre-tests, post-tests, and a two-week delayed post-test of the vocabulary words were administered to determine the effectiveness of the flash cards. The assessments demonstrated that flash cards were effective at increasing student acquisition of vocabulary and overall increased student engagement (Grillo & Dieker, 2013).

Inquiry-based teaching is a technique that allows students to construct their own knowledge on a topic instead of the teacher directly disseminating information. It often involves having students access background knowledge on a subject, introducing new information and guiding students as they incorporate into their prior knowledge, and finally having students reflect on the learning process. Research suggests that inquiry-based learning cycles result in better acquisition and retention of science vocabulary and concepts and improve process skills compared to traditional instructional methods (Duran & Duran, 2004).

One method of teaching science content is the evocation, realization of meaning, and reflection strategy which provides teachers an instructional framework to improve critical thinking and analysis by teaching students to determine the context of their own knowledge. A study was performed to determine the effectiveness of this instructional framework among secondary science teachers. The framework is composed of three phases which model how people learn. In the first phase, evocation, students use their background knowledge on a subject to determine the purpose of learning about the subject. Next, during realization of meaning, students are exposed to new content and incorporate it into their prior knowledge. In the final phase, reflection, students reflect and evaluate their learning (Terzic, 2012). By surveying teachers participating in the study, teachers felt the framework was effective and increased student engagement. Additionally, teachers reported the most effective vocabulary strategies were knowledge rating charts, graphic organizers, word sorts, and categorizing words from text (Nixon, Saunders, & Fishback, 2012). The framework is similar to other learning models such as the 5E Instructional Model.

The 5E instructional model is an inquiry-based methodology developed from research in cognitive psychology and constructivist learning theories. It consists of five stages of learning: engage, explore, explain, extend, and evaluate. The engage stage is a student-centered stage where students observe scientific phenomenon or discuss open-ended questions. The purpose of this stage is to increase student interest and motivation and for the instructor to assess prior knowledge and student misconceptions. During the explore stage, students use active exploration to problem solve and apply processing

skills to construct their knowledge of the event or question presented during the engage stage. In the explanation stage, the lesson moves from student-centered hands on to a more teacher-directed thinking stage guided by student understanding from the explore stage. In this stage students express their thoughts and describe their experiences. They synthesize their experience with information provided through instruction from the teacher. The elaboration stage allows students to apply their new knowledge of the concepts through application in new settings or disciplines, further investigation, and development of products. Finally, the evaluation stage allows formal and informal assessments to determine students understanding of science concepts (Duran & Duran, 2004).

In one study, the clue word strategy was used to improve vocabulary acquisition and retention with high school English language learners that also had reading disabilities by teaching the students how to look for context clues to determine word meaning. The clue word strategy combines both contextual and word analysis strategies that have previously shown to be effective in expanding content vocabulary of students. After a baseline had been established, students received a series of clue word strategy instructional lessons. Pretest and posttest assessments were used to evaluate the effectiveness of the intervention. Results of this study indicated that the clue word strategy effectively improved all students' ability to analyze and predict word meanings of unknown science words. The limitations of the research were discussed and it was recommended that the study be repeated with a larger student population (Helman, Calhoun, & Kern, 2015).

A three-week long study was designed to compare the effects of three instructional strategies on student comprehension of photosynthesis and respiration in plants in 8th grade science. The researchers conducted their study in three classes and instruction covered the same content. In one of the classes, content was delivered using the conceptual change model of instruction, the second class received content through the 5E instructional model, and the third class acted as the control in which content was delivered through the traditional direct teaching model. The students were randomly selected, and the same teacher taught all three classes. Assessment instruments were used before and after the investigation to collect data. The researchers found that the 5E instruction model group scored significantly higher than the control group ($p=0.028$). Additionally, the conceptual change instructional model group also demonstrated better performance and comprehension than the control group ($p = 0.025$). The researchers did not find a significant difference in the performance of the 5E group compared to the conceptual change group ($p = 0.968$). In conclusion, the investigation demonstrated that students acquired content knowledge more effectively through the 5E and conceptual change instructional models than traditional direct instruction (Balci, Cakiroglu, & Tekkaya, 2006).

Gamification is the use of game playing elements in non-gaming environments like the workplace or educational settings. Gamification can be implemented in online and traditional classroom settings and frequently utilizes online platforms although this is not a requirement for implementation of this instructional strategy. A major component of gamification is the use of a reward system such as points, badges, leader scoreboards,

and opportunities to level up to once mastery at a specific level has been achieved (Abrams & Walsh, 2014).

A study conducted an online gaming intervention to determine the effect of gamification on learning outcomes and motivation of one hundred undergraduate students as they learned about the national taxation system. The students participated in a group decision-making system in a prediction market. Students were required to create group forecasts based on uncertain future events from which they bought or sold contracts and invested virtual cash. Independent research informed the students during decision making and forecasting. Students were given continuous feedback through the online gamification environment and rewarded with virtual cash, increasing the value of their portfolio, when good decisions were made. Gamification had a positive result on learning outcomes and significantly increased students' general knowledge ($p < .005$) as determined by and pre- and post-intervention survey. The gamification intervention showed a positive correlation with motivation and participation ($p \leq .05$) (Buckley & Doyle, 2016).

In a different study, the online platform Vocabulary.com was used to determine the role of gamification in adolescents' vocabulary development and attitudes toward learning vocabulary. The online gamification intervention was conducted with eleventh grade students and young adults and implemented in an after-school program and an in-school classroom. Students were given custom word lists to learn through Vocabulary.com to supplement literacy instruction and reading assignments. The gamified features of Vocabulary.com gave students real-time feedback, allowed them to

earn badges and level up when mastery was attained. Students were given control over their learning and could self-monitor their progress. Vocabulary challenge games were then played in class which provided students opportunities to collaborate in teams and compete against each other. At the end of the intervention, students were on average scoring higher on vocabulary assessments than prior to the intervention, and students were expressing increased motivation, enjoyment, and confidence in learning the vocabulary (Abrams & Walsh, 2014).

In summary, the literature has shown that intentional vocabulary instruction supports students' understanding of scientific concepts. Due to the sophisticated academic vocabulary in science, students need help in learning and processing academic vocabulary and language to become independent science learners (Snow, 2010). After carefully analyzing vocabulary that is crucial to understanding the content, teachers have many research-based strategies they can choose from to implement vocabulary instruction in their classes. Research has also demonstrated that a focus on vocabulary instruction will benefit students with learning disabilities and English language learners. Inquiry-based instructional strategies such as, the 5E instructional model and gamification, have been shown to be effective in increasing motivation and improving students acquisition and comprehension of science concepts.

METHODOLOGY

This action research-based classroom project was conducted January through March 2017 during which data were collected to determine the effectiveness of different inquiry-based instructional strategies on improving students' acquisition of science

vocabulary. The traditional direct instruction strategy was compared against the inquiry-based instructional strategies 5E Learning Cycle and gamification. Each instructional strategy was applied for approximately two weeks during the physics unit in three freshman level physical science classes ($N=87$). All three physical science classes received the instructional strategy treatments at the same time. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

During implementation of the direct instruction teaching strategy, students were taught primarily through lectures and note taking, followed by practice worksheets and application of concepts through lab activities. Students were given access to Quizlet vocabulary study sets and encouraged to review vocabulary at home. The Direct Instruction Physics Vocabulary Assessment was administered prior to and after instruction to assess the effects of this instructional strategy on student acquisition of physics vocabulary terms (Appendix B).

For each topic presented during implementation of the 5E Learning Cycle instructional strategy, students were presented with a discrepant event during the *engage stage* to increase interest in the learning topic. Students were then allowed the opportunity in the *explore stage* to investigate the physics concept on their own and begin to construct their own knowledge. The *explain stage* involved discussion of student observations during the explore stage and supplemented with direct instruction. Physics vocabulary words were connected to the observations and explanations generated by

students. Next, in the *extend stage*, students were asked to build on the information they had learned and apply it in a new situation, using the science vocabulary words. Finally, the *evaluation stage* consisted of administering the 5E Learning Cycle Physics Vocabulary Assessment before and after instruction to determine the effects of the 5E Learning Cycle teaching strategy on student acquisition of physics vocabulary (Appendix C).

Implementation of the gamification instructional strategy consisted of students competing in teams for points. Students were placed in teams of four so that each team was balanced with high and low achieving students. In addition to placing students by academic ability, the personality and individual strengths of each student were taken into consideration so that teams were an even mix of extraverts that have high participation in lecture and introverted students that prefer to be more reserved in large group activities. Each day, students could earn points for their team by participating in lecture by answering and asking thoughtful questions, correctly answering a daily trivia question related to scientific concepts currently being covered, placing in the top 5 during the review games, making study flashcards, and scoring well on the unit quiz. Students lost points for their team being tardy to class, having electronic devices confiscated by the teacher, being disrespectful to others, and noncompliance with teacher requests. Physics concepts were taught through a mix of direct instruction, inquiry, and lab activities. Vocabulary words were reviewed through a variety of games including the online platforms Kahoot and Quizlet Live. The Gamification Physics Vocabulary Assessment

was given to students before and after instruction to determine the effects of gamification instructional strategies on student acquisition of physics vocabulary (Appendix D).

In each of the vocabulary assessments described above, students were required to match six vocabulary words to their definitions as well as apply their knowledge of the vocabulary terms to solve a set of conceptual and analytical problems. Paired t-tests were used to compare pre-and post- assessment scores and test for a null hypothesis.

To assess student attitudes toward the vocabulary instruction, and their perception of the effectiveness of the different instructional strategies the Student Input Survey was given after implementation of the Capstone project (Appendix E). The survey was constructed using multiple Likert scale items in which students were asked to indicate their level of agreement with how effective each instructional strategy was in helping them learn the physics vocabulary terms. The post-treatment Likert data was analyzed by comparing their responses and determining which instructional strategies students liked the best and felt were most effective in helping them learn the vocabulary terms.

Students from each physical science class ($N=8$) were randomly selected to be interviewed before treatment to determine what vocabulary study strategies they already utilized (Appendix F). The same students were interviewed after treatment to determine which inquiry-based instructional strategy they felt was most effective in helping them learn the vocabulary terms each week (Appendix G). The interview responses were analyzed for emerging themes from which a claim could be made regarding the effectiveness of inquiry-based instructional strategies and supported with evidence from

student quotes. The data collection methods are summarized in the Triangulation Matrix (Table 1).

Table 1
Data Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
1. What is the effectiveness of direct instruction instructional strategy on student acquisition of science vocabulary words?	Direct Instruction Physics Vocabulary Assessment	Student Input Survey	Interviews
2. What is the effectiveness of 5E Learning Cycle instructional strategy on student acquisition of science vocabulary words?	5E Learning Cycle Physics Vocabulary Assessment	Student Input Survey	Interviews
3. What is the effectiveness of gamification instructional strategy on student acquisition of science vocabulary words?	Gamification Physics Vocabulary Assessment	Student Input Survey	Interviews

DATA AND ANALYSIS

Student interviews prior to implementation of the treatment revealed that students were, for the most part, not studying science content vocabulary outside of the classroom. When students were asked how they study science content vocabulary almost all of the students replied that they do not study at all beyond the activities we do in class. One student stated, “I go over my notes before a quiz or test but that’s about all.” Of the students that did study outside of class, a student stated her mom quizzes her on science terms at home, and another said she uses teacher created Quizlet study sets to learn science content vocabulary words on her own time. All of the interviewed students cited

online games played in class such as Kahoot and Quizlet Live helped them learn vocabulary best.

Analysis of student pre- and post-test scores of the Direct Instruction Physics Vocabulary Assessment, 5E Learning Cycle Physics Vocabulary Assessment, and the Gamification Physics Vocabulary Assessment showed that all three methods supported students in learning science vocabulary words ($N=87$). Analysis of pre- and post-test scores, using paired t-tests, resulted in a p -value of 0.00 for all three instructional strategies. Therefore, all three instructional strategies made a significant difference ($p<0.05$) in student learning of science content vocabulary from the pre-test to the post-test.

The mean student score for each instructional strategy increased on the post-test as compared to the pre-test scores. Both the direct instruction and 5E Learning Cycle had a mean pre-test score of 58%. The mean pre-test score for gamification was 56%. Of the three instructional strategies, the 5E Learning Cycle had the highest average post-test score of 83%. Direct instruction had an average post-test score of 79%, and gamification had the lowest with 77%.

The standard deviation for each instructional strategy decreased from the pre-test to the post-test. The standard deviation of the 5E Learning Cycle instructional strategy went from 21 for the pre-test to 10 for the post-test, a decrease of 11 points. In comparison, the standard deviation of both direct instruction went from 18 to 14 from pre- to post-test and gamification from 22 to 18, both instructional strategies decreased the standard deviation by 4 points.

In addition to having the highest average post-test score and lowest standard deviation, the lowest individual post-test scores were much higher on the 5E Learning Cycle Physics Vocabulary Assessment than both the Direct Instruction Physics Vocabulary Assessment and the Gamification Physics Vocabulary Assessment. This shows the 5E Learning Cycle was likely more effective at increasing the lowest student scores than the direct instruction and gamification instructional strategies (Figure 1).

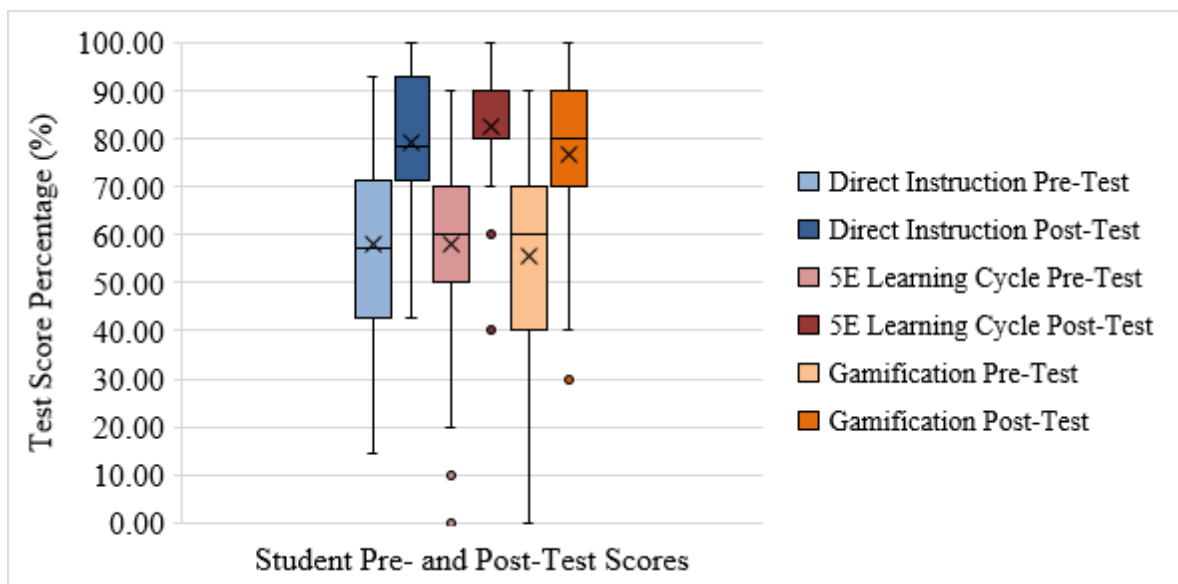


Figure 1. Box-and-whisker plot of pre-and post-test scores for direct instruction, 5E learning cycle, and gamification instructional strategies, ($N=87$).

The average normalized gain, which is a measure of effectiveness, was 0.46 for direct instruction teaching strategy, 0.49 for 5E learning cycle, and 0.39 for gamification. These values indicate all three instructional strategies had a *medium* level (0.3-0.7) of impact on increasing student learning of physics vocabulary words with the 5E learning cycle being slightly more effective than the other two strategies and gamification being the least effective (Hake, 1998). An ANOVA test was completed to compare normalized gains of all three instructional strategies. The test resulted in a p -value of 0.49 indicating

that there was not a significant difference in student outcomes between each instructional strategy.

The average response rating was calculated for each question in the Student Input Survey given after implementation of the treatment. Each student response was analyzed using the following scale: 1 = strongly disagree, 2= disagree, 3 = neutral, 4 = agree, 5 = strongly agree. The three gamification strategies of playing games in partners or teams, Kahoot, and Quizlet Live had the highest average rating scores. Direct instruction strategies of learning vocabulary through notetaking during lectures and reading a text book had the lowest average scores (Figure 2).

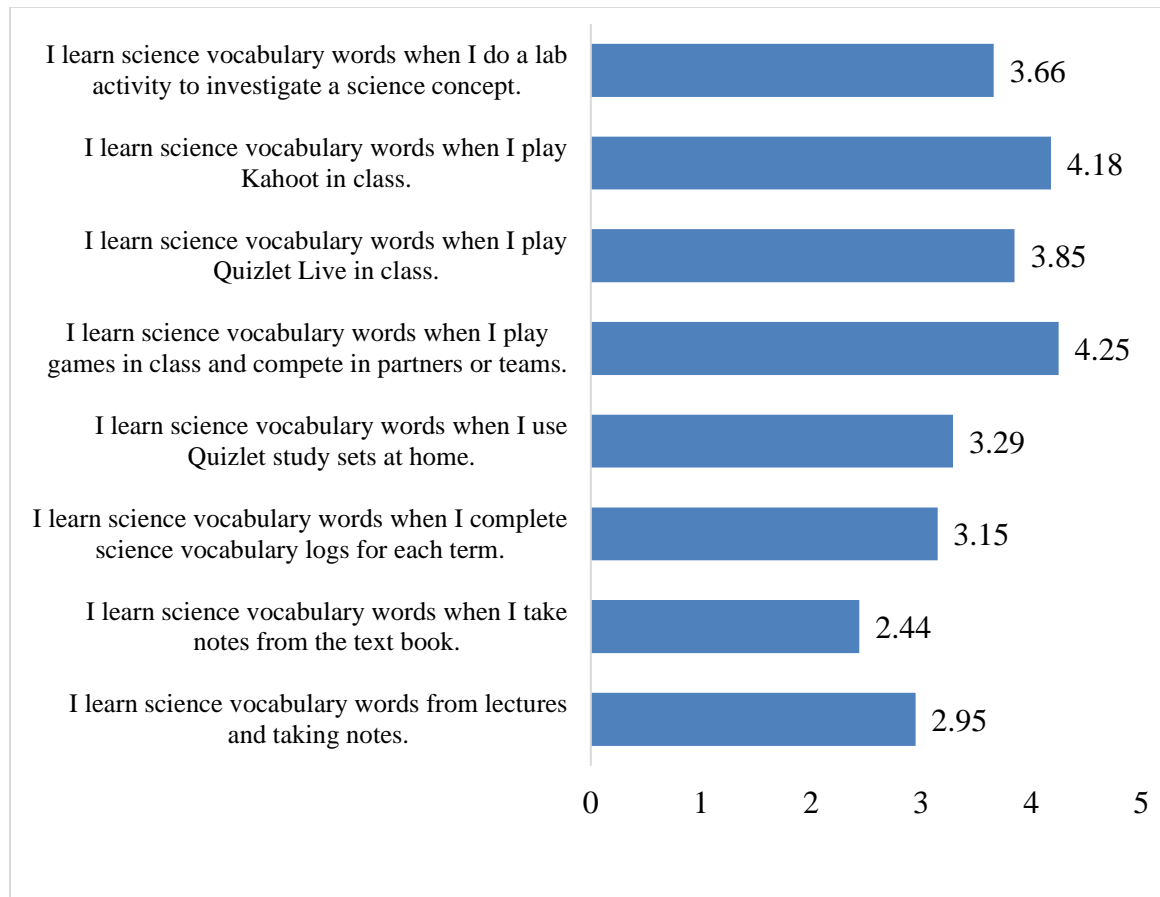


Figure 2. Average response rating on student input survey.

Note. 5=strongly agree, 4=agree, 3=neutral, 2=disagree, 1=strongly disagree, (N=87).

Additionally, each student response was analyzed to determine the percent breakdown of student ratings for each Likert survey item (Figure 3). Based on student responses, students felt that gamification instructional strategies best help them learn science content vocabulary. Eighty-four percent of students *agreed* or *strongly agreed* that playing games in partners and teams helped them learn vocabulary, 78% *agreed* or *strongly agreed* that playing Kahoot helped them learn vocabulary, and 65% *agreed* or *strongly agreed* that playing Quizlet Live helped them learn vocabulary. Inquiry-based lab activities also scored high among students with 65% stating that they *agree* or *strongly agree* these activities help them learn vocabulary. Learning science vocabulary words from taking notes from a text book scored the lowest with 62% of students stating they *disagree* or *strongly disagree*.

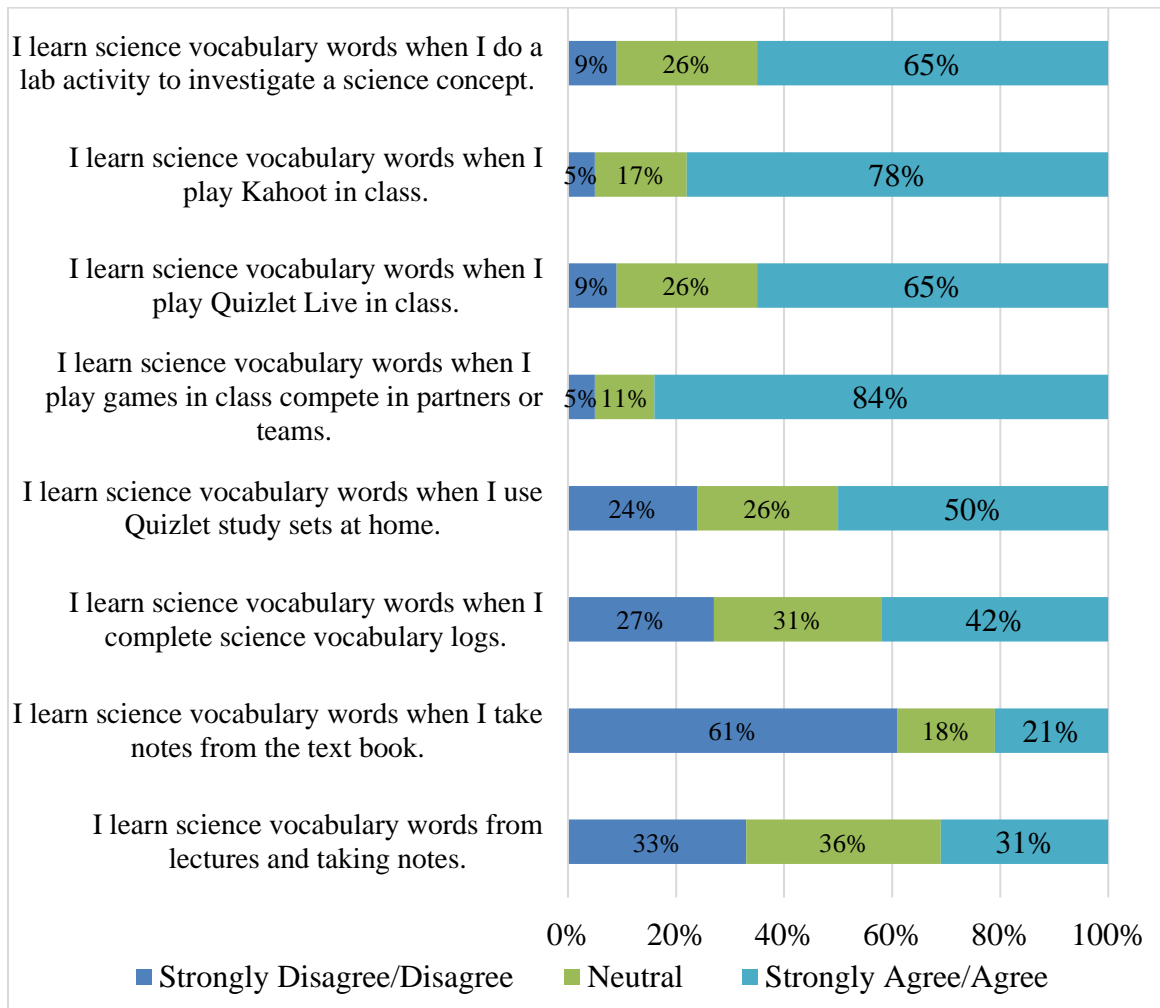


Figure 3. Percent of student ratings per survey question, (N=87).

In post-treatment interviews, a majority of students claimed the 5E Learning Cycle was the instructional strategy they liked the best. One student stated he liked this strategy “because it was more active.” Another student said, “I like the labs. It was more interactive and it helped me understand the notes better.” Two students interviewed stated they liked the gamification instructional strategy the best. One student felt the game aspect “made me more motivated to answer questions in class and pay attention.” The

second student stated, “Playing in teams made class more fun and competitive. It was less boring.”

INTERPRETATION AND CONCLUSION

Although the ANOVA test showed that there was not a significance difference in normalized gains between the three instructional strategies, other data presented indicates the 5E Learning Cycle was likely the most effective of the three instructional strategies in increasing student acquisition of science content vocabulary words. Direct instruction and gamification had similar impacts on student learning. Both of these strategies increased the average student score by 21 percentage points from the pre-test to the post-test. In comparison, the 5E Learning Cycle increased the average student score by 24 percentage points. While the standard deviation between pre- and post-test decreased for all three tests, the standard deviation of the 5E Learning Cycle decreased almost three times that of direct instruction and gamification strategies. This shows the range of student test scores were much less spread out after the 5E Learning Cycle treatment as compared to the other strategies, indicating it was more effective than direct instruction and gamification.

The lowest pre-test student scores for all three instructional strategies ranged from 0-20%. On the post-test for direct instruction and gamification, the lowest student score ranged from 40-45%. Comparatively, the lowest post-test student score for the 5E Learning Cycle strategy was 70%. This demonstrates that implementation of the 5E Learning Cycle was likely more effective for the students that struggle with learning science vocabulary the most than direct instruction and gamification strategies.

From a student perspective, direct instruction is the least effective in helping them learn science vocabulary. Direct instruction strategies were rated the lowest on the Student Input Survey. In post-treatment interviews, several students stated that this strategy was boring. Students rated aspects of gamification the highest on the survey followed by components of the 5E Learning Cycle indicating these strategies were the most well received by students, and students felt these strategies helped them learn science vocabulary words best.

In post-treatment interviews, students clearly enjoyed the 5E Learning Cycle and gamification instructional strategies. They felt both strategies were more interactive and made class more interesting. Students identified that the gamification strategy increased their motivation and desire to do well so they could earn points for their team. Of the two instructional strategies enjoyed by students, they felt the 5E Learning Cycle helped them learn the science vocabulary words more than gamification. One student stated, “It was easier to learn the vocabulary words because I could connect the examples and labs with the definition of the vocabulary word.” Another student said, “Seeing lots of demonstrations and real-world examples made it click in my head when taking the test. I could visualize the vocab words.”

VALUE

This research project has shown me that inquiry-based instructional strategies can effect positive change in student acquisition of science content vocabulary, leading to overall improvement in student learning outcomes. Students clearly enjoyed the 5E

Learning Cycle and gamification instructional strategies and felt it improved their motivation, engagement in class, and understanding of science vocabulary terms.

Moving forward, I plan to approach instruction in my classroom using the 5E Learning Cycle with elements of gamification weaved in. I am going to explore more online gamification platforms such as Classcraft where students can work together as teams while also earning individual points to level up their individual avatar.

Additionally, I am very interested in incorporating the online platform Vocabulary.com into my curriculum. Based on my literature review, this platform provides vocabulary practice for students and differentiates instruction based on the student's current level. I feel the gamified features of this platform will increase student engagement as students are able to self-monitor their progress and encourage learning of science content vocabulary through a system of reward badges and leveling up. I would also like to expand my focus on vocabulary instruction from science content specific vocabulary terms to general academic vocabulary, descriptive science literacy vocabulary, and scientific metalanguage terms used by students for scientific processing.

This research project has led to the following question: *how effective will implementing the 5E Learning Cycle and gamification instructional strategies be on improving acquisition of science vocabulary for low achieving students? Also, how will intentional vocabulary instruction through these inquiry-based instructional strategies improve scientific literacy for all students? What effect will it have on their ability to engage in academic conversations, reading comprehension, and scientific writing?*

In addition to building off of and expanding this research in the future, I would like to share my results and insights with my school community. My hope is that in sharing my experience, my colleagues will be encouraged to implement inquiry-based instructional strategies to improve student vocabulary acquisition and literacy in their specific content areas.

Participating in this research process has reinvigorated and greatly improved my teaching practice. I feel inspired and excited about implementing what I have learned from this classroom-based research project into my curriculum next year. Additionally, I have become more reflective and thoughtful as an educator, and I have begun to journal about my daily experiences in the classroom. The action research process has given me a framework from which I can address and investigate future issues that arise in my classroom and school community. Not only do I feel more empowered as an educator, but I feel that I have learned how to give students a voice and opportunities to express their experiences and perspectives.

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APPENDICES

APPENDIX A
IRB EXEMPTION



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MEMORANDUM

TO: April Idar and John Graves
FROM: Mark Quinn *Mark Quinn CJ*
DATE: December 12, 2016
SUBJECT: "Effect of Inquiry-Based Instructional Strategies on Student Acquisition and Retention of Science Content Vocabulary" [A1121216-EX]

The above research, described in your submission of December 12, 2016, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

DIRECT INSTRUCTION PHYSICS VOCABULARY ASSESSMENT

Name: _____

Physics Vocabulary Assessment #1*(Teaching strategy: Direct Instruction)**Assessment modified from Active Physical Science, Volume 1 (Eisenkraft, 2005)*Vocabulary & Definitions Matching*Match each vocabulary term with its correct definition.*

- | | |
|---|---|
| 1. Acceleration | A. Natural tendency of an object to remain at rest or to remain moving with constant speed in a straight line. |
| 2. Newton's 1 st Law of Motion | B. A push or a pull that is able to accelerate an object. |
| 3. Weight | C. An object at rest remains at rest, and an object in motion remains in motion with a constant speed in a straight-line path unless acted upon by an unbalanced force. |
| 4. Inertia | D. The acceleration of an object is proportional to the magnitude of the force and in the same direction as the net force and inversely proportional to the mass of the object. |
| 5. Force | E. The vertical downward force exerted on a mass as a result of gravity. |
| 6. Newton's 2 nd Law of Motion | F. The change in velocity over time. |

Applying Vocabulary Terms

Using your knowledge of the vocabulary terms, answer each question below.

7. Which of the following best illustrates Newton's First Law of Motion?
 - a. A collision between a running back and a linebacker in football.
 - b. An ice hockey puck sliding along the ice after being hit by a player's stick.
 - c. A bowling pin being struck by a bowling ball
 - d. A volleyball being "spiked" across the net

8. A person sliding into second base continues to slide past the base due to:
 - a. Inertia
 - b. Friction
 - c. Weight
 - d. Gravity

9. Newton's First Law of Motion states that an object at rest stays at rest unless acted upon by a _____:
 - a. Balanced force
 - b. Net force (unbalanced)
 - c. Weak force
 - d. Strong force

10. An object rolling across a level floor without any horizontal net force acting on it will:
 - a. Slow down
 - b. Speed up
 - c. Keep moving forever

11. What force would be needed to accelerate a 0.040-kg golf ball at 20.0 m/s^2 ?
 - a. 0.02 N
 - b. 500 N
 - c. 0.8 N
 - d. 20.04 N

12. What happens to a person's weight as they stand on a planet with more mass than Earth?
- a. Weight increases
 - b. Weight decreases
 - c. Weight remains constant

APPENDIX C

5E LEARNING CYCLE PHYSICS VOCABULARY ASSESSMENT

Name: _____

Physics Vocabulary Assessment #2*(Teaching strategy: 5E Learning Cycle)**Assessment modified from Active Physical Science, Volume 1 (Eisenkraft, 2005)*Vocabulary & Definitions Matching*Match each vocabulary term with its correct definition.*

- | | |
|------------------------------------|---|
| 1. Work | A. Stored energy that is dependent on the position of an object. |
| 2. Newton's 3rd Law of Motion | B. The point at which all the mass of an object is considered to be concentrated. |
| 3. Kinetic Energy | C. For every applied force, there is an equal and opposite force. |
| 4. Center of Mass | D. The product the force applied to move an object and the amount of displacement of the object. |
| 5. Coefficient of Sliding Friction | E. The energy an object possesses because of its motion. |
| 6. Potential Energy | F. The relationship between the force required to slide an object and the perpendicular force exerted by the surface on the object. |

Applying Vocabulary Terms

Using your knowledge of the vocabulary terms, answer each question below.

7. “Center of gravity” means essentially the same thing as “center of mass”. Why is it often said to be desirable for football players to have a low center of gravity?
 - a. They can get a head start when running for the ball
 - b. They can jump higher when catching the ball
 - c. They are more stable to withstand a tackle

8. How much work does a male figure skater do when lifting a 50-kg female staking partner’s body a vertical distance of 1 meter?
 - a. 50 Joules
 - b. 490 Joules
 - c. 50 Newtons
 - d. 490 Newtons

9. For a hit in baseball, compare the force exerted by the bat on the ball to the force exerted by the ball on the bat. Why do wooden bats sometimes break?
 - a. The bat exerts a larger force on the ball
 - b. The ball exerts a larger force on the bat
 - c. The bat and ball exert an equal but opposite force on each other

10. Explain why sprinters prefer to use longer spikes on their shoes than long distance runners, even though both run on the same track surface.
 - a. Spikes increase applied force on the track which quickly increases the sprinter’s acceleration
 - b. Spikes add mass to the runner which increases the force the runner applies to the track
 - c. Long distance runners want to decrease the overall amount of work they do. Not wearing spikes decreases the amount of force being applied on the track.

APPENDIX D

GAMIFICATION PHYSICS VOCABULARY ASSESSMENT

Name: _____

Physics Vocabulary Assessment #3*(Teaching strategy: Gamification)**Assessment modified from Active Physical Science, Volume 1 (Eisenkraft, 2005)*Vocabulary & Definitions Matching*Match each vocabulary term with its correct definition.*

- | | |
|-----------------------------|--|
| 1. Centripetal Force | A. The inward radial acceleration of an object moving at a constant speed in a circle. |
| 2. Momentum | B. In a closed system, the total momentum before a collision will be the same after a collision. |
| 3. Centripetal acceleration | C. The force that acts on an object moving in a circular path and is directed toward the center around which the object is moving. |
| 4. Speed | D. The product of the mass and velocity of an object. |
| 5. Centrifugal Force | E. The change in an object's distance over time. |
| 6. Conservation of Momentum | F. An apparent force that acts outward on an object moving in a circular path, arising from the object's inertia. |

Applying Vocabulary Terms

Using your knowledge of the vocabulary terms, answer each question below.

7. Suppose a running back collides with a defending linebacker who has just come to a stop. If both players have the same mass, what do you expect to see happen in the resulting collision?
 - a. The defending lineman would move back and the speed of the running back would decrease
 - b. Both players would stop
 - c. The speed of both players would increase

8. Describe the collision of a running back and a linebacker of equal mass running toward each other at equal speeds.
 - a. The two players will continue to move forward
 - b. The two players will bounce backwards
 - c. The speed of each player will increase

9. A railroad car of 2,000 kg coasting at 3.0 m/s overtakes and locks together with an identical car coasting on the same track in the same direction at 2.0 m/s. What is the speed of the cars after they lock together?
 - a. The momentum after the collision is less than the before the collision
 - b. The momentum after the collision is more than before the collision
 - c. The momentum after the collision is the same as before the collision

10. When you twirl an object on a string in a circular path, the string provides the _____.
 - a. Centripetal Acceleration
 - b. Centripetal Force
 - c. Centrifugal Force

APPENDIX E
STUDENT INPUT SURVEY

Which teaching strategies do you feel helped you best learn science vocabulary? Rate each strategy using the scale below.

Please give your honest feedback. This survey is anonymous and is not for a grade.

1. I learn science vocabulary words from lectures and taking notes.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

2. I learn science vocabulary words when I take notes from the text book.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

3. I learn science vocabulary words when I complete science vocabulary logs for each term by writing the word and definition with a picture, example, or equation.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

4. I learn science vocabulary words when I use Quizlet study sets at home.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

5. I learn science vocabulary words when I play games in class related to a science concept and compete in partners or teams.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

6. I learn science vocabulary words when I play Quizlet Live in class.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

7. I learn science vocabulary words when I play Kahoot in class.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

8. I learn science vocabulary words when I do a lab activity to investigate a science concept.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

APPENDIX F
INTERVIEW QUESTIONS BEFORE TREATMENT

1. How do you study science vocabulary words?
2. What activities do we do in class that help you learn science vocabulary words?
3. Are there things that other teachers do that really helps you learn the vocabulary in those classes?
4. Is there anything I can do, that I am not doing already, that will help you learn science vocabulary words?

APPENDIX G
INTERVIEW QUESTIONS AFTER TREATMENT

1. Which of the teaching strategies did you like the best (direct instruction, 5E Learning Cycle, Gamification, etc.)? Please explain why.
2. Which of the teaching strategies do you feel helped you best learn the science vocabulary (direct instruction, 5E Learning Cycle, Gamification, etc.)? Please explain why.
3. Is there anything else you would like to add? Do you have any recommendations or ways to improve the teaching strategies?