THE IMPACT OF VOCABULARY INSTRUCTION ON SCIENCE LEARNING IN A SECONDARY SCIENCE COURSE

by

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TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

LIST OF TABLES

Table Page

LIST OF FIGURES

ABSTRACT

This investigation focused on the most effective instructional strategies for helping students learn science vocabulary in a ninth grade biology classroom (*N*=30). Students were divided into two groups, and received instruction using either established methods, control group (*n*=15), or innovative methods, intervention group (*n*=15). The investigation continued during two units of instruction (approximately three weeks each), with students receiving different instructional treatment for each unit. Innovative methods were informed by several vocabulary learning theories, most specifically Social Constructivism/Sociocultural Theories, Schema and Psycholinguistic Theories, Dual Coding Theory, and Motivation Theory. Student growth was measured using pretests and posttest of vocabulary terms, and analyzed using normalized gain. Vocabulary performance showed larger normalized gains for the intervention group. Mean normalized gain for the intervention group was 0.653, while mean normalized gain for the control group was 0.483. Other measures of student learning were also collected, with surveys giving insight into student preferences. A Likert scale survey measuring preference and confidence showed slightly more positive responses for the intervention group An open-ended survey analyzed using word clouds also indicated slightly more positive responses by students in the intervention group. Finally, student scores on vocabulary posttests and summative unit tests showed a positive correlation between vocabulary acquisition and broader classroom success. Linear regression of student unit test scores (mean for both units) versus posttest scores (mean for both units) showed that 45% of test score differences were explained by differences in vocabulary posttests. This investigation showed that intervention methods were more effective at helping students learn science vocabulary, were slightly preferred by students, and had a strong correlation with broader measures of student performance in this biology classroom.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

Killian Hill Christian School (KHCS) is an independent, religious K-12 school located in suburban Atlanta, GA. Enrollment for the school in grades Kindergarten through 12th grade is approximately 420 students, with approximately half of these students in the Secondary School comprising grades 7th-12th. The school has a very diverse population, including approximately 50% Black or African American students, 20% Caucasian students, 10% Hispanic students, and 15% Asian students, and 10% students of multiple races (US News and World Report | Education, 2021). Academic culture at KHCS is emphasized with virtually all students graduating and a large number pursuing postsecondary education (Baker, 2021).

The science department at KHCS in the Secondary School includes one full-time science instructor (myself) teaching five courses, and three teachers who each teach one science course. This study will be conducted in the biology course. Students typically take this course in 9th grade.

The process of teaching science requires continual decisions about allocating limited resources to meet several competing priorities. Student time, focus and energy, teacher time and energy, and the time that teachers and students are together in class are all limited resources. These resources are used to drive growth by students in several areas, including science practices like inquiry and argumentation, disciplinary core ideas like the principles and laws that describe the natural world, and communication skills like the ability to read and write using the content-specific language particular to the subject.

My own teaching practice has included different approaches to the relative allocation of the educational resources of time and energy to meet the three broad goals of science practices, disciplinary core ideas, and communication. Early in my teaching career, I emphasized disciplinary core ideas. In the last few years, I have emphasized the science practices. Both emphases have produced very positive outcomes for at least some students. My goal with this study is to optimize the distribution of time and energy in the classroom so that students can achieve the best possible success in all three areas: (a) understanding disciplinary core ideas, (b) implementing science practices, and (c) communicating clearly about science. This last goal, communicating about science, includes both generating information through writing and speaking, and receiving information by reading, listening, and watching.

Reflection on the performance of the students in my classes indicated that communicating clearly about science presents the greatest opportunity to produce improvement, so this investigation attempted to measure whether overall growth in student performance benefited from increased focus on the communication goal through the inclusion of focused vocabulary-acquisition instruction.

Focus Question

The purpose of this study was to determine the effect of an intervention replacing traditional vocabulary learning activities with innovative activities that emphasize mastery of scientific vocabulary by students. Students who receive a mode of traditional instruction that has been established in this class (the control group) were compared with an intervention group of students who engaged in vocabulary learning activities informed by the theories that explain how learners acquire new vocabulary. To help determine the effect of these intervention activities, the following questions were investigated.

My focus question was, What effect will the innovative vocabulary learning activities produce on the academic growth of students in my classroom?

My sub questions included the following:

1. How does vocabulary acquisition differ when using intervention vs established instructional methods?
2. How do students respond subjectively to intervention and established instructional methods for learning vocabulary?
3. How is vocabulary acquisition related to general science performance in my classroom?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

The Challenge

Teaching science to secondary school students presents several challenges due to the varied nature of the knowledge, skills, and dispositions that students are expected to gain. Students are expected to behave like scientists by gaining experience in designing and performing investigations in a variety of settings. Science education is expected to help students become scientifically literate citizens who have a critical outlook when building their own arguments and evaluating the arguments of others. Most areas of science require students to incorporate mathematical routines and mathematical thinking to arrive at answers. In many cases the routines and thinking are specific enough that they must be developed through science courses. Not least of all, science students are expected to communicate with others in both receiving and sharing information.

This last skill, communicating scientific information, requires students to master a large body of scientific vocabulary. Groves (2016) performed a longitudinal study of a selection of middle school and high school texts published since 2010, and found that the domain-specific vocabulary load in these books remains high, despite recommendations by some teaching organizations to reduce the vocabulary emphasis. His survey of commonly used science texts found that the number of domain-specific terms in most texts numbered between 1000 and 2000. Groves found that this corresponds to a vocabulary load that is as heavy as in foreign language courses. Similarly, Ardasheva and Tretter (2017) argued that challenging courses like those in the high school science curriculum require mastery of both general academic language and science-specific vocabulary.

Gaining comprehension of content-specific vocabulary is an important struggle for all students, but the process is especially difficult for certain populations. Groves (2016), as well as Ardasheva and Tretter (2017), identified students where English was a second language as especially likely to be unprepared for the domain-specific vocabulary demand of science courses without special support. Seifert and Espin (2012) noted that students with a learning disability often experienced a mismatch between the reading level that students can achieve and the reading level required by the texts. Poor achievement of science standards is frequently the result.

Possible Solutions

Science-specific vocabulary puts large demands on students and has a large impact on the process of communicating science information, both when students receive information and when they share it. This creates a situation where a thorough understanding of the process by which students gain word knowledge is an important tool for science educators as they try to improve student outcomes. Moody et al. (2018) performed a meta-analysis of research from the previous decade that indicated four main ideas that guide understanding of vocabulary acquisition. Those four areas are Social Constructivism/Sociocultural Theories, Schema and Psycholinguistic Theories, Dual Coding Theory, and Motivation Theory. Each of the four main modes for understanding how a learner develops vocabulary are described briefly below, along with the corresponding activities that a teacher could develop to help learners develop vocabulary.

Social Constructivism/Sociocultural Theories emphasized the need for connection with others through social interactions to help learners construct knowledge. Social Constructivism/Sociocultural Theories emphasized the Zone of Proximal Development (ZDP), which bridges the areas where students can and cannot currently perform. As understood by these theories, interactions between knowledgeable individuals (like a teacher) and learners (students) can help learners develop further, especially if the interactions are structured and scaffolded. Vocabulary learning activities influenced by Social Constructivism/Sociocultural Theories will involve input from and collaborative discussion among many learners to develop the meaning of words.

Four Theories of Vocabulary Instruction

Schema and Psycholinguistic Theories describe the mental filing cabinets and hierarchical organization of knowledge that learners use to organize the facts and ideas that they are learning. These theories describe how “a readers’ background knowledge interacts with conceptual abilities and processing strategies to produce comprehension” (Moody et al., 2018, p. 5). Vocabulary learning activities built on Schema and Psycholinguistic Theories ask learners to connect words to synonyms and antonyms, consciously build connections among terms by using concept maps or other graphic organizers, analyze words using the prefixes, roots, and suffixes they contain, and consciously connect prior knowledge to predict possible meanings for new terms (Moody et al., 2018).

Dual Coding Theory recognizes that two major methods of cognition - or codes, verbal and nonverbal, exist, with the best comprehension occurring when learners connect knowledge in both codes. Vocabulary instruction activities that consider Dual Coding Theory will often involve multiple modalities, focus on concrete and imageable examples, and intentionally elicit mental images (Moody et al., 2018).

Motivation Theory focuses on the increase in learning that occurs when students can recognize the alignment between their own goals and the learning task they are undertaking. They indicate that "motivation also can increase through extrinsic means, such as achieving learning goals based on competition or the desire for external rewards or praise" (Moody et al., 2018, p. 6). Activities that consider Motivation Theory to encourage vocabulary learning can include "the development of word consciousness to enhance student interest, the use of word-learning games, and technology-based activities" (Moody et al., 2018, p. 6).

Moody et al. (2018) found that these theories are not mutually exclusive but can provide a complementary understanding of the process of learning new words. The intervention methods of vocabulary instruction for this research project employed understanding of all four of the theoretical constructs informing the learning of vocabulary. Social Constructivism/Sociocultural Theories made the smallest impact on the design of the intervention, with the other three, especially Motivation Theory, impacting the design of learning tasks in significant ways.

Examples of Vocabulary Learning Theories Put into Practice

With these theories undergirding the teaching, several interventions have been attempted by other researchers to improve student comprehension and retention of word learning with a variety of students. Watts-Taffe et al. (2019) described a strategy that they named the Four E's of Vocabulary Instruction. This approach focuses on teacher talk and student talk, and includes Explain, Engage, Extend, and Examine behaviors. The *Explain* behavior involves a dialogue between the teacher and learners, and among learners, that helps construct the meaning of the word, using student-friendly terms. The *Engage* behavior involves tasks that ask the student to analyze and cognitively process the new word. The *Extend* behavior sets up activities that ask students to break down the word into parts, connect it with prior knowledge, provide examples, and use alternative modalities like pictures to represent the word. The *Examine* behavior involves assessing student knowledge frequently. Although the terminology is not explicitly present, many of the behaviors present during the Four E behaviors seem to be influenced by a complementary mix of the theoretical understanding of the vocabulary learning theories described by Moody et al. (2018). When using this method, Watts-Taffe et al. emphasized the importance of using the four E's in a context that is meaningful to students, and applicable to the domain of the vocabulary being learned. The use of the Four E behaviors was reported to be effective in helping students acquire new words at a very meaningful level in a variety of classrooms.

Another intervention by Page and Mede (2018) compared task-based instruction and traditional instruction for improving comprehension and retention of vocabulary. They described Task Based Instruction (TBI) as being embedded language acquisition during the execution of real-world communication tasks. These tasks facilitated the use of authentic sources, motivated learners, and helped make the language that they learned concrete and connected to the students' own lives. Traditional instruction (TI) in this study focused on teacher-led direct instruction about the meaning of the vocabulary (Page & Mede, 2018). Page and Mede found that a hybrid approach that included some aspects of both TI and TBI instruction modes was most effective. These interventions provide examples of strategies that promise significant gains in the achievement of vocabulary learning goals.

Another study was conducted to investigate the most effective method of helping students grow their vocabulary. Karami and Bowles (2020) studied the effectiveness of using intentional vocabulary instruction, incidental vocabulary instruction, or a mixture of both. Students were measured using an immediate posttest and a delayed posttest. Although they did not use the terms, the intentional vocabulary instruction seemed to be informed primarily by the Schema and Psycholinguistic Theories as described by Moody et al. (2018) by asking students to analyze words and their parts, focus on denotative meanings, and identify synonyms and antonyms. The incidental vocabulary instruction was similar to the Task Based Instruction described by Page and Mede (2018) and emphasized vocabulary in context of some task or goal that transcends merely knowing additional words. The results of their study indicated that students performed best when a mixture of both methods was used. In fact, Page and Mede found that although all groups had lower performance on the delayed posttest than the immediate posttest, the mean score of students in the mixed group was higher on the delayed posttest than either of the other groups even on the immediate posttest. As Moody et al. described, it seems that using a complementary understanding of the theories for vocabulary learning is most effective.

It is clear from the meta-analysis by Moody et al. (2018), and the interventions studied by Watts-Taffe et al. (2019) and by Page and Mede (2018) that teacher preparation and behavior can have a significant impact on student learning of vocabulary. These theories provide a framework for vocabulary acquisition that the teacher can leverage to get insight into what is going on inside their students' heads. The intervention strategies show that the challenging but important task of helping students gain the communication skills needed to be scientifically literate citizens can be accomplished. This research project investigated whether application of these theoretical constructs, and teacher behavior similar to these successful interventions can improve students' acquisition of science-specific vocabulary. The goal was to determine if the vocabulary learning activities that take into account the theories of language learning can help their students build their science vocabulary, as well as determining if fluency with scientific vocabulary allows the learners to be successful in more meaningful ways in the science classroom.

CHAPTER THREE

METHODOLOGY

Demographics

The purpose of this study was to determine the effect of innovative vocabulary learning activities on the academic growth of students in my classroom. My classroom is the Biology I classroom at Killian Hill Christian School (KHCS), an independent religious, K-12 school located in Atlanta, GA. Enrollment for the school in grades Kindergarten through 12th grade is approximately 420 students, with about half of these students in the Secondary School comprising grades 7th-12th grade. The school has a very diverse population, including approximately 50% Black or African American students, 20% Caucasian students, 10% Hispanic students, and 15% Asian students, and 10% students of multiple races (US News and World Report | Education, 2021). Academic culture at KHCS is emphasized with virtually all students graduating and a large number pursuing postsecondary education (Baker, 2021).

Biology I is offered to any students who have completed a course in physical science, which means that this course is typically taken by ninth grade students. Students who are continuing their education at KHCS will have taken a life science course in sixth grade that introduces students to many of the same topics that we investigate further in the high school biology curriculum. However, enrollment at KHCS frequently has some change as students move to ninth grade, with several students leaving for other schools, and several students enrolling at KHCS for the first time as students transition into high school. For this reason, although most students have some knowledge of the ideas, I teach the Biology I course with very few assumptions about the prior biological knowledge of the students. This cohort of students in Biology I (*N*=30) has naturally been impacted by the ongoing disruptions to education brought about by the COVID-19 pandemic.

Performance on the Iowa Test of Basic Skills (ITBS), used to provide norm referenced achievement scores, was distinctly lower in 2021 than in previous years for KHCS. The Complete Composite score reported for this test ranked this group of students at the 83rd percentile in 2021, where it had the same cohort of students at the 94th percentile in 2019 (the most recent previous test, since no tests were administered in 2020). Before the COVID-19 pandemic impacted school, this cohort outperformed the KHCS longitudinal average at their grade (94th vs 75th percentile in 2019 when they were in 6th grade), but after the pandemic the same cohort underperformed the KHCS longitudinal average for their new grade (83rd vs 89th percentile in 2021 when they were in 8th grade). Appendix A shows more details on the school's standardized achievement scores.

Many students were online for some or all of the previous school year, as both KHCS and surrounding schools offered online options. This year (2021-22) all students at KHCS participated in on campus learning. Students who chose online learning options at KHCS seemed to have negative impacts on their learning. Schoolwide, all KHCS students who chose online learning showed a learning deficit of 0.5 years, as measured by the Iowa Test of Basic Skills (ITBS). The students currently in ninth grade who were at KHCS the previous year for standardized testing showed a marked drop in performance, especially in mathematics. The online-learning students were behind their on-campus classmates by more than a whole grade.

Appendix B shows the differences in performance for online and on campus students on the school's ITBS testing.

Although some differences in students in the ninth grade can be attributed to the choice of online or on campus learning environment, there were marked differences that were present in students that are separate from their learning environment. I taught the same cohort of students in eighth grade in one of two physical science classes and saw many differences. At that time, the group was separated based on previous performance in math and science courses into College Prep Physical Science and Honors Physical Science. The students in the Honor Physical Science course showed much higher levels of many of the traits that make students successful in school. Students in the honors section of physical science had much higher levels of verbal engagement (both asking and answering questions), lower percentage of incomplete assignments, had data collection and analysis skills in the lab that were much more mature, and engaged in scientific argumentation (both written and verbal) that was much more mature than the students in the College Prep Physical Science course. In the ninth grade Biology I classroom, these groups of students - at least, those who returned for ninth grade - were mixed, along with new students. The composition of the class is students formerly in Honors Physical Science (n=10), students formerly in CP Physical Science (n=10), and students new to KHCS (n=10). The overarching goal of this research project was to learn about the effect of intervention instructional strategies on students in order to pinpoint teacher behaviors and student activities that work to support this wide variety of students in being successful in vocabulary acquisition, and in the course as a whole. The research methodology for this project received an exemption by Montana State

University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A).

Treatment

With the goal of learning what effect the intervention instructional strategies will have, but having a single class of widely varying students, an experimental design was chosen that used groups that had a mixture of new students, students who had previously been in Honors Physical Science, and students who had previously been in CP Physical science. The class was divided into two groups, Group A and Group B. Each group had 15 students, 5 each from the new students who were previously in honors and students previously in CP groups. Student performance was measured over the course of two units, Genetics and Gene Express. The Genetics unit focused on introductory, mostly Mendelian genetics, and the Gene Expression unit, focused on the central dogma processes of DNA replication, transcription, and translation. In the first unit, Group A received the control treatment, and Group B received the intervention treatment. In the second unit, the groups were switched, with Group A receiving the intervention treatment, while Group B received the control treatment (Figure 1).

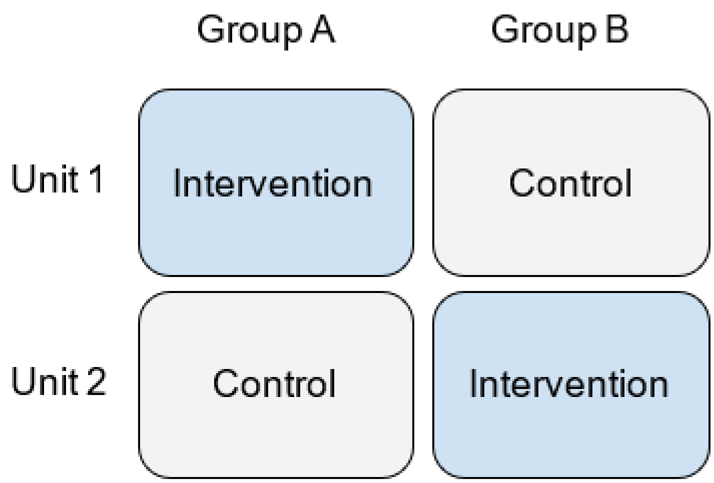

Figure 1. Experimental design.

Control Group

The vocabulary learning activities for the control group were traditional for my classroom. Students were given a list of vocabulary terms and asked to write definitions for these terms using the text and class notes. To ensure that each student performed the task, but were able to keep their work, students submitted pictures of their hand-written definitions to Google Classroom, our school's Learning Management System. Students were encouraged to study these notes independently in preparation for a vocabulary quiz. After they submitted their hand-written definitions, students were also given access to a set of electronic flashcards on Quizlet that had teacher-created definitions for each term. Students were encouraged to study these terms at least three days a week for the entire unit.

Intervention Group

The vocabulary learning activities for the intervention treatment were new for this classroom. Students were asked to contribute to a group set of definitions to the same vocabulary terms on a shared Google Slides document. The goal of asking students to contribute as part of a group was to leverage the Social Constructivism/Sociocultural Theories. Moody et al. (2018) describe the learning that occurs during participation in an activity as part of a group that constructs meaning. Since this task decreased the time investment from students by allowing collaboration, students were asked to construct a concept map for the terms from this unit. Each concept map showed the connections among the terms in the unit. Asking students to consciously consider this hierarchy among terms and the many ways in which the terms are connected was influenced by the Schema and Psycholinguistic Theories, which Moody et al. (2018) describe as focusing on the mental arrangement and analysis of words (p. 5). Students were also given access to a set of electronic flashcards on Quizlet that had teacher-created definitions for each term. This set was identical to the set shared with the control group, except that it had a picture representing the term to leverage the Dual Coding Theory that Moody et al. (2018) describe as emphasizing multiple modalities including visualizations. Teacher behavior that considered the Motivation Theory was also facilitated by the Quizlet. The teacher tools that Quizlet provides allowed confirmation of which days students had studied on. Students who studied these terms at least three separate days a week for each week of the unit were recognized verbally and given a virtual badge.

Data Collection and Analysis Strategies

Data Collection Methods

The data triangulation matrix below repeats the specific questions related to the broad focus question for this research and indicates which data collection instruments were used to provide data to answer each of the specific questions. As a reminder, the focus question for this research project was, What effect will the innovative vocabulary learning activities produce on the academic growth of students in my classroom? (Table 1).

Table 1. Data Triangulation Matrix.

	Focus Questions		
Data Collection Instruments	How does vocabulary acquisition differ when using intervention vs established instructional methods?	How do students respond subjectively to intervention and established instructional methods for learning vocabulary?	How is vocabulary acquisition related to general science performance in my classroom?
Vocabulary Pre- and Posttests	X	X	X
Likert Scale Student Surveys	X	X	X
Open Ended Student Surveys		X	
Unit test	X		X

The cycle of data collection and instruction for each of the two units is shown visually in Figure 2, below.

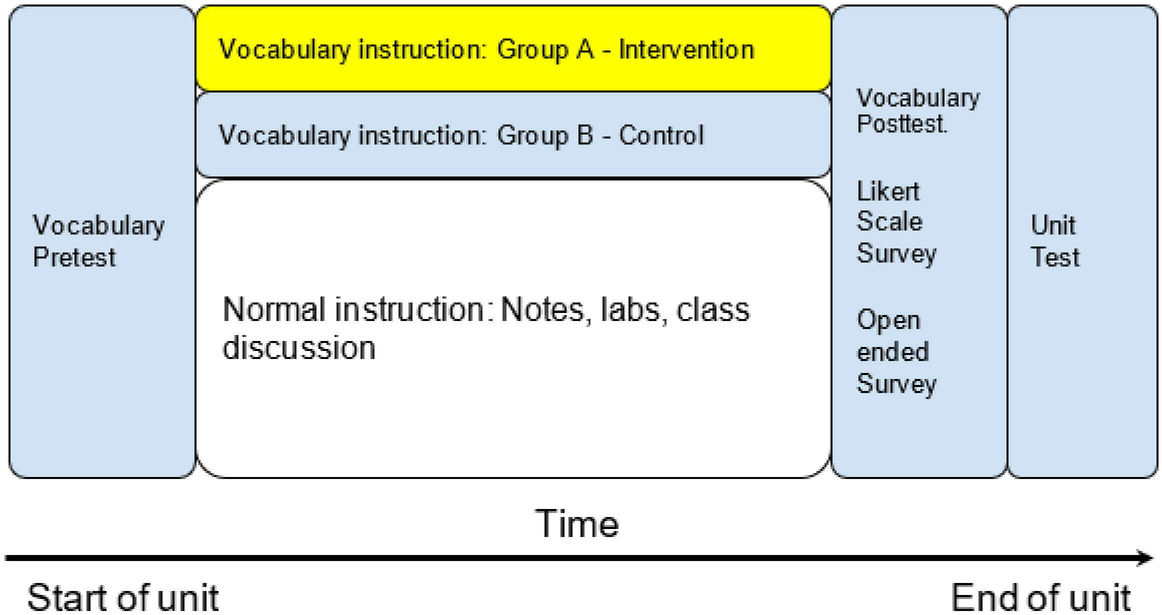

Figure 2. Data collection and instruction cycle. For Unit 2, Group A and Group B switched treatments.

Instrument Justification

Vocabulary Pre- and Posttests

To determine the effectiveness of the intervention methods of vocabulary acquisition, student growth was measured for two groups. For one unit of study, approximately three weeks of instruction, students from the biology class was divided into two treatment groups. The control group engaged in the established vocabulary learning activities that have been typical for this class - writing definitions of words and independent study of these terms. The experimental group engaged in the intervention activities for vocabulary learning. Both groups had their comprehension of the important terms for the unit measured at the beginning and at the end of the unit. The growth in vocabulary comprehension was measured by finding the normalized gain in comprehension for each group of students. The same items will be included in the pretest and posttest, with the order shuffled. Both pretest and posttest were administered in class, with students responding through a Google form.

Student Surveys

Two brief surveys were used to collect data about students' subjective responses to the two methods of instruction. The surveys were primarily used to collect data to answer the second focus question, How do students respond subjectively to intervention and established instructional methods for learning vocabulary? Surveys are an effective way to gather information about students' attitudes, perceptions, and opinions (Mertler, 2020, p. 145). Mertler (2020) further indicates that surveys allow a large amount of data to be collected quickly and analyzed easily. This data was useful in assessing the overall value of an instructional method. For example, a method of instruction that is slightly more effective in helping students to learn, but which has a much higher subjective cost to the students because it mismatches student preference might not be worthwhile. Because confidence and comfort during learning tasks can often impact the learning experience of students, data from the first survey will also be useful in providing some context for answering the first focus question, How does vocabulary acquisition differ when using intervention vs established instructional methods? The surveys were administered at the end of each unit, during the last class before the unit test, which is a review period. Both surveys will be administered online using Google Forms.

The first survey included several items which students rate using a 1-5 Likert scale indicating the degree to which they agree with the statement included in that item. Items asked students to indicate the degree of comfort, confidence, engagement and enjoyment they had with the vocabulary instruction for that unit. Survey items can be seen in Appendix D. A Likert survey is appropriate for finding this kind of data, according to Horst et al. (2018) because it helps gain an understand of the attitudes, perceptions, thoughts, and experiences of students. The results of the first survey were analyzed, and differences between preference and confidence for students in the two groups were helpful in providing context and subjective insight into students' mindsets. This insight was used in interpreting the objective data provided by analysis of normalized gains in vocabulary between the two groups.

The second survey asked open-ended questions about levels of engagement with learning activities, and what students enjoyed and disliked about the learning activities. The questions for the second survey can be seen in Appendix E. This survey allowed collection of qualitative data that provides insight into student perceptions of the effectiveness and enjoyment that the learning activities from the different instructional approaches provided them. Data was analyzed using word clouds to help determine patterns and trends in the student responses to the differing instructional activities. These patterns and trends were very useful in choosing whether future instruction should continue using the established learning techniques or change to the new techniques. Additionally, student insights were helpful in determining future refinements and minor changes that could be made to whichever approach is chosen.

Unit Tests

The final specific research question for this action research project was, How is vocabulary acquisition related to general science performance in my classroom? To learn the connection between vocabulary and general science performance, data was collected from the Unit Test at the end of the two units that comprise the study. Students were grouped into control and experimental groups. The average student performance (as a percentage) and standard deviation for each group and for each individual student was recorded. The process is repeated in the second unit, with students having swapped treatment groups. Following both units, each student's average score on the unit tests was plotted against that student's average score on the vocabulary posttests. A linear regression was performed to infer the degree of correlation vocabulary performance and overall performance in my classroom.

Analysis Strategies

Addressing the focus question for this research project required having some level of confidence that differences in outcome can be attributed to the differences in vocabulary learning activities, not differences in the group of students. To validate that any differences in learning are due to the instructional method rather than the students in the group, the process will be repeated for a second unit of study, with students switching treatment methods. The method of analyzing data to uncover differences will depend on the type of data produced by the different data collection instruments, and the specific question that this data collection instrument is trying to answer.

Vocabulary Pretests and Posttests: Analysis of Normalized Gains

Student performance on vocabulary pretests and posttests was analyzed using normalized gain. According to McKagan, Sayre, and Madsen (2017), average normalized gain, $<g>$, is calculated using the formula $< g > = \frac{<post> - <pre>}{100 - <pre>}$, where angled brackets indicate group averages, and “pre” and “post” represent pretest and posttest scores, respectively, expressed as percentages. It represents the amount that scores did improve, divided by the amount that scores could improve. McKagan, Sayre, and Madsen described normalized gain as “the amount students did learn divided by the amount students could have learned” (para. 3). Data collected from the normalized gains of the experimental and control groups allowed for quantitative comparisons of the effectiveness of the instructional methods. Coghlan and Brydon-Miller (2014) described quantitative research as the collection and analysis of numerical data. Mertler (2020) described the importance of quantitative data, as it can be analyzed and can provide some objective criteria for choosing between two alternatives. Richard Hake (1998), in his classic article introducing normalized gain, described it as a measure of the effectiveness of instruction, and it has been used broadly in educational research since then. This data collection method is intended to answer the question, How does vocabulary acquisition differ when using intervention vs established instructional methods?

Student Surveys: Comparison of Group Mean and Word Clouds

The two surveys described above were used to collect subjective data about student preferences and confidence. To analyze data collected in the Likert scale survey, the mean of student responses was compared. The Likert scale had numerical values, ranging from 1 for Strongly Disagree to 5 for Strongly Agree. All the prompts indicated positive traits, like “I enjoyed the activities that I participated in to learn the scientific terms for this unit,” or “I feel prepared for the test on this unit.” Since all the prompts represent a positive response by students, larger numerical values indicated more desirable outcomes. Comparing the mean response for the groups of students will allow insight into the students’ subjective perception of the learning activities. Before being analyzed, surveys were administered twice, once at the end of each unit. Responses were then analyzed by comparing the treatment group to the control group, with the responses of all students included.

The analysis was performed both for the entire set of questions and for individual items on the Likert Scale Survey. Entire set analysis was performed by summing the numerical value of the response to each item for the student, then comparing the mean values for the two treatment groups. This allowed a comparison that summarized the level of positive response for students in the intervention vs control treatment. At the level of the individual items, the analysis was made by comparing the mean of the responses to each item on the survey for students in the treatment group against the mean for students in the control group. This allowed me to gain insight into the specific perceptions of students in the control vs treatment groups. Because of the subjective nature of the data measured by these surveys, differences in the group means were not analyzed for statistical significance, and insight gained from these tests was used to give context and meaning to the more objective measures collected in the normalized gains on vocabulary tests and the unit tests.

For the second survey, which contained open-ended prompts, analysis was performed using word clouds. Student responses were collected via Google Forms, then the data was copied and pasted into a word cloud online software program. The program removed words which do not contribute to meaning (articles, pronouns, etc.) then counted the frequency of the remaining words. The resulting word list was used to generate a word cloud that increased the size of frequently repeated words and decreased the size of infrequently repeated words. This allows a visual representation that shows trends and patterns in open-ended verbal responses. This second survey provided qualitative data that complemented the quantitative data collected in the other data collection instruments. Along with the quantitative but still subjective data from the other survey, the data from this open ended survey was helpful in putting the other results in context, and helping to interpret the objective data.

Unit Tests: Comparison of Group Averages and Linear Regression

The student performance on unit tests was also measured. The analysis of this data was based on the mean for students in each group, for the two unit tests. The standard deviation for each group (control and intervention treatment) was also measured on each of the two unit tests.

Comparison was made by calculating the mean group performance on each test, then summing the performance for each treatment on the two tests. Since the treatment group in the first unit was the control group in the second unit, it was hoped that any variation due to individual differences would average out. The sum of averages for treatment and control treatments could then be compared. However, in order to make a more holistic comparison of the association between vocabulary posttest score and unit test scores, a linear regression was performed. This linear regression compared the average of unit test scores against the average of posttest scores.

CHAPTER FOUR

DATA ANALYSIS

Results

Vocabulary Pretest and Posttest

The first instrument used for data collection was the pretest and posttest of vocabulary terms administered at the beginning and end of each of the two units of study. The Genetics unit was the first involved in this action research project, while the second unit focused on the central dogma of biology and is designated using the name DNA-Protein in these results. The posttest scores were higher than the pretest scores for both units of study. In each case, the intervention group showed average pretest scores that were lower and posttest scores that were higher than the control group. Although there were differences between the groups, the difference was not large in any of the cases. Table 2 shows the mean scores (out of 20 possible) for the pretest and posttest for each unit, while Figures 3 and 4 below provide visualizations of the results.

Table 2. Mean number correct on each of the vocabulary assessments for Control (*n*=15) and Intervention (*n*=15) groups. There were 20 possible correct responses.

	Control	**Intervention**
Genetics | Pretest	7.15	5.33
DNA-Protein | Pretest	6.78	5.46
Genetics | Posttest	13.33	14.23
DNA-Protein | Posttest	13.20	15.62

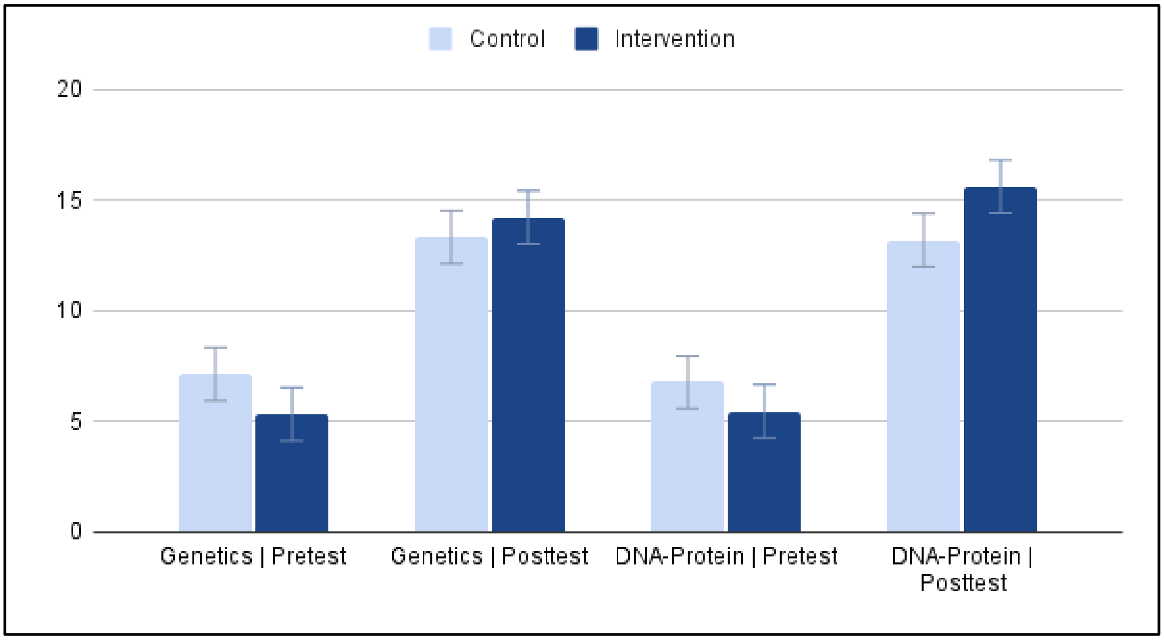

Figure 3. Mean number correct on each of the vocabulary assessments for Control (*n*=15) and Intervention (*n*=15) groups. This figure groups results by assessment.

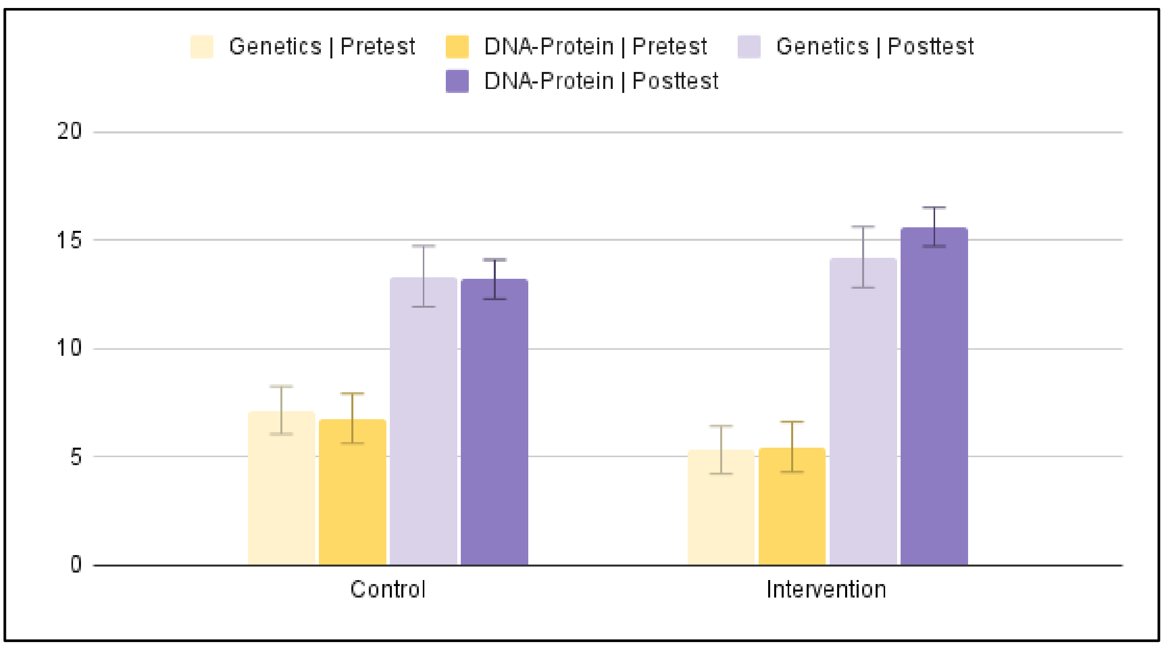

Figure 4. Mean number correct on each of the vocabulary assessments for Control (*n*=15) and Intervention (*n*=15) groups. This figure groups results by treatment.

Analysis of the results of the pretest and posttest data was conducted using the calculation of normalized gain <*g*>. For this investigation, the intervention group showed higher normalized gain (g=0.653) than the control group (g=0.483). This pattern was true for each of the two units studied, as well as the average normalized gain for both units together (Table 3). Figures 5 and 6 show the difference in normalized gain on the vocabulary tests for the two groups.

Table 3. Normalized gain <g> for Control (*n*=15) and Intervention (*n*=15) groups during each of the two units, and for the average of both units together.

	Control	**Intervention**
Normalized Gain | Genetics	0.481	0.607
Normalized Gain | DNA-Protein	0.486	0.698
Normalized Gain | Average	0.483	0.653

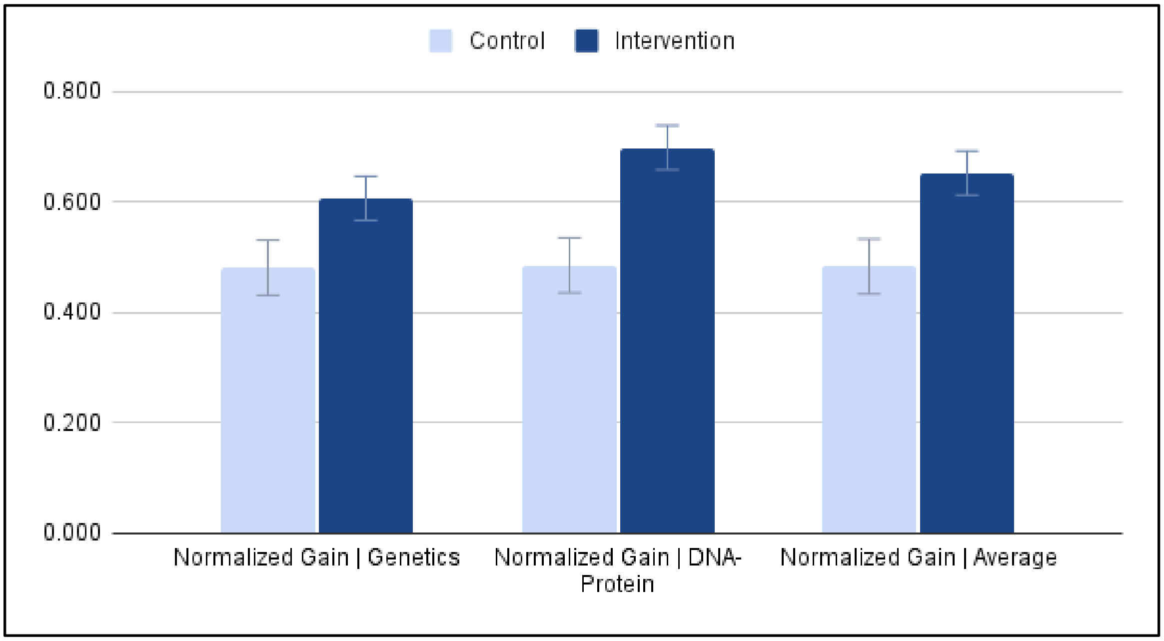

Figure 5. Normalized gain <g>. This figure groups results by instructional unit, with the average of the two units shown in the final grouping.

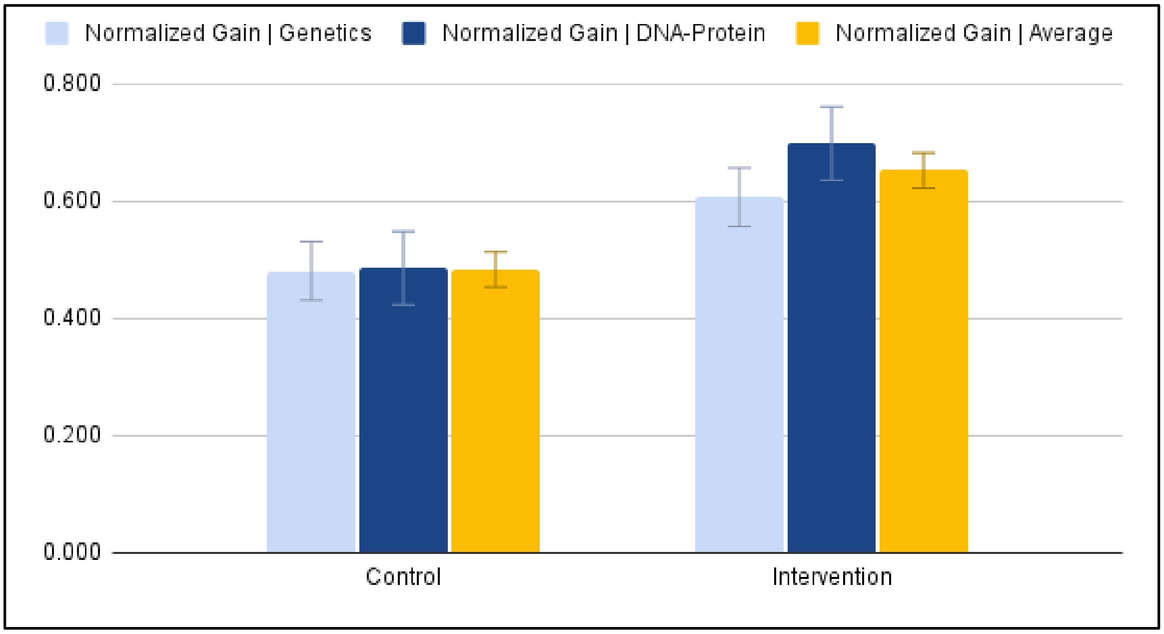

Figure 6. Normalized gain <g>. This figure groups results by treatment.

Likert Survey

The second instrument for collecting data in this action research project was a Likert survey, administered at the end of each of the two units of study. Student responses to this survey showed that they were more likely to have positive responses when they were involved in the intervention learning activities than when they were involved in the control learning activities. Positive responses were interpreted as responses that would agree or strongly agree with statements indicating confidence and preparedness, enjoyment of the learning activities for themselves or as perceived in their classmates, or recommendation that future students use the same learning activities as they had used. Negative responses were interpreted as responses that would disagree or strongly disagree with the statements.

Student responses were slightly more positive for the intervention group than the control group. The control group (*n*=15) had a total of 45.5% positive responses indicating either agree (26.8%) or strongly agree (18.8%). The intervention group (*n*=14) had 48% positive responses, including 32.7% agree and 15.3% strongly agree. The differences are most notable in items four and five of the survey, which asked students if they could talk about this unit with a student and help them understand (item 4), and if they felt prepared for the test on this unit (item 5). In both cases, the control group had 38% positive responses while the intervention group had 50% positive responses. Student responses for the intervention group also included fewer negative responses than for the control group. This is especially notable on item 4, where 38% of the control group but only 14% of the intervention group disagreed or strongly disagreed about the statement indicating that they could talk to a student about the unit. A similar difference was seen for item 5, which showed that 44% of students in the control group had a negative response, while 29% of students in the intervention group responded negatively by indicating “Disagree” or “Strongly Disagree” to the prompt about feeling prepared for the unit test.

Figure 7 and Figure 8 below show the percentage of students who responded with each level of agreement or disagreement to each of the seven statements on the survey, for the control group (Figure 7) and the intervention group (Figure 8).

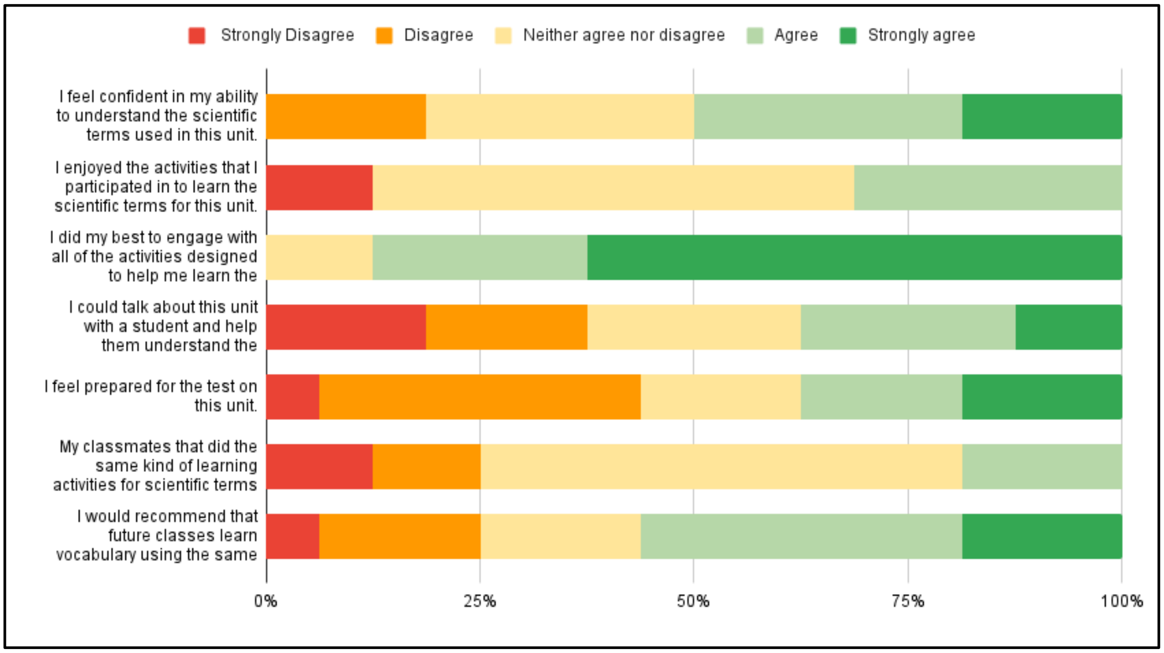

Figure 7. Likert survey data for control group (*n*=15).

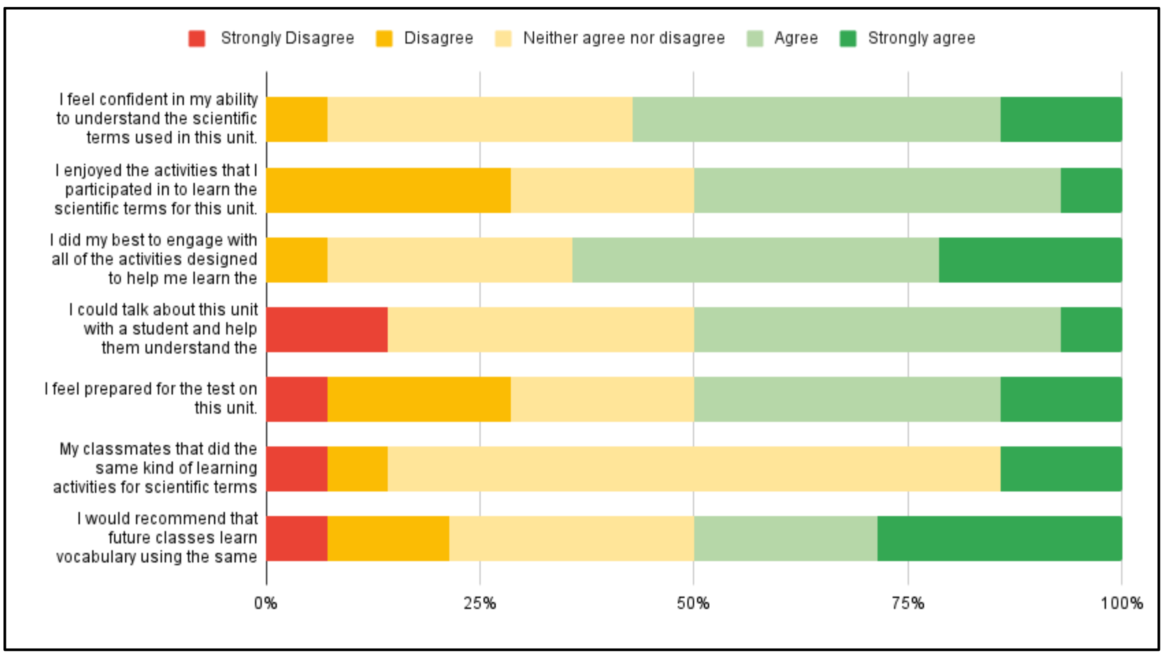

Figure 8. Likert survey data for intervention group (*n*=14).

The shift in the intervention group toward more positive responses (more light green and dark green) is evident on the graphs in Figures 7 and 8 for all of the prompts except one.

Students indicated more agreement with statements indicating that they felt confident, enjoyed the activities for learning vocabulary, and could talk to a fellow student to provide help. Intervention group students and control group students had similar percentages of positive responses to prompts that they perceived that their classmates enjoyed the learning activities (control 19%, intervention 14%), and that they recommended future students learn using their method (control 56%, intervention 50%).

The only prompt about which students in the intervention group were less likely to give positive responses was the third. This prompt asks students to indicate to what level they agreed that, "I did my best to engage with all the activities designed to help me learn the terms for this unit." For this question, the control group had a higher level of agreement than the intervention group. Control group students had 88% positive responses (25% agree, 63% strongly agree), while intervention group students had 64% positive responses (43% agree, 21% strongly agree). For this prompt, neither group had many negative responses, with 0% of control group students and 7% of intervention group students disagreeing or strongly disagreeing with the statement about doing their best.

By assigning values of 1 for "Strongly Disagree" through 5 for "Strongly Agree," it is possible to give quantitative comparisons of the group responses. Figure 9 below shows the mean of the numerical values assigned to the responses for each of the seven prompts in the Likert survey. The higher values shown for the Intervention group (dark columns) show the slightly more positive subjective response of students in that group to the intervention activities for all prompts except the one indicating effort. Although the Intervention groups did show higher mean values, all of the differences were small.

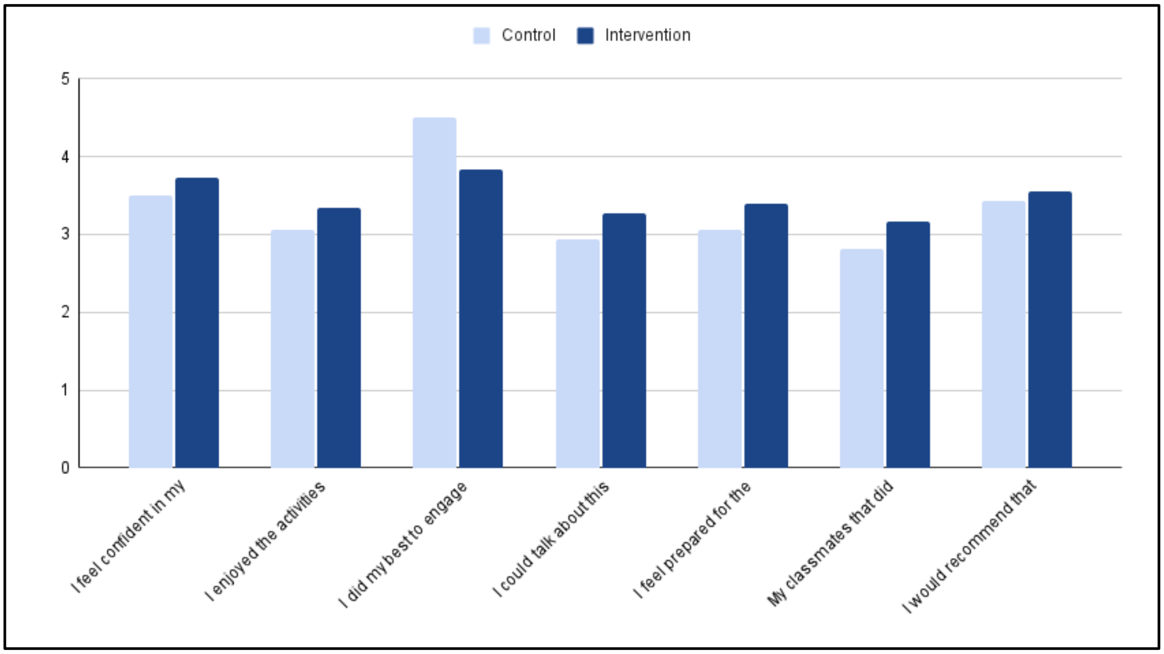

Figure 9. Mean of student responses for each Likert survey item for Control (*n*=15) and Intervention (*n*=15) groups.

Analysis data from the first two data collection instruments demonstrates that the intervention techniques for learning vocabulary were more effective in improving student achievement on vocabulary acquisition activities. The higher posttest scores for the intervention group at the end of both units, despite lower pretest scores, shows more learning. This was verified by higher normalized gains for the control group during each of the instructional units. Improvement in performance matched the higher level of confidence shown in the Likert survey. Students in the Intervention group were more likely to have positive responses to the prompts that indicated that they were confident in their own ability, that they could talk to a fellow student about the content of the unit, and that they felt prepared for the unit test. Although none of the differences were large, the consistent pattern of slightly more positive responses by students in the intervention group comported with students who are better prepared for success.

The data from the Likert survey was also helpful in providing insight into the second focus question for this action research, How do students respond subjectively to intervention and established instructional methods for learning vocabulary? The responses to the Likert survey seem to indicate that students have a more positive response when they are involved in the intervention vocabulary learning activities than when they are involved in the control activities. Whole-group comparisons between the control and intervention group could be facilitated by comparing the sum of the means of numerical values from each prompt in the survey. The intervention group had a slightly higher sum, 24.3 than the control group, 23.3. In addition to the higher confidence levels seen in the intervention group, students were also more likely to indicate positive responses to prompts associated with enjoying the learning activities. The second and sixth prompts would produce agreement if the student himself/herself or the student's classmates, respectively, enjoyed the vocabulary learning activities. Although again the differences were small, the consistent pattern of slightly higher rates of positive responses indicate that the intervention activities were aligned at least as well as the control activities with student preferences.

Open-Ended Survey

The third data collection instrument, the open-ended survey, helped provide additional context to the data in from the Likert survey. The data were analyzed using word clouds generated by a free online word cloud generator, wordclouds.com. Once responses were collected using the Google form version of the survey (which can be viewed in Appendix E), responses were filtered into control and intervention groups, and then copied and pasted into the input of the word cloud program. Figure 10 and Figure 11 below show the word clouds generated by responses from the control group and intervention group.

Figure 10. Word cloud generated from responses to the open-ended survey by the control group (n=7).

Figure 11. Word cloud generated from responses to the open-ended survey by the intervention group (*n*=11).

Recognizing trends in the responses to this open-ended survey was difficult, even with the assistance of the word clouds. Sadly, student engagement with this task was not as high as was hoped, with only 18 students submitting meaningful responses. Although with these limitations in place, it would be inappropriate to put very much weight behind this data, some patterns can be at least tenuously identified.

One pattern that can be hypothesized in the emphasis that students in the control group put on the work involved in the task itself. The word cloud in Figure 10 includes several words connected to the task-oriented nature of the control group activities. Words like “definitions,” “process,” “structure,” “writing,” “vocabulary,” and “definitions” seem to give some insight into the mindset of the students as they approach the learning activities for the control group. A student quote might be illustrative of this mindset. One student said, “Although it was a long and difficult process, it was more helpful when trying to memorize and match them with their definitions.” Another student said, “Writing them [the terms and their definitions] down.” Both of these quotes were given in response to the prompt “What are some of the things that seemed most helpful to you in learning scientific terms for this unit?” This focus on the task-oriented nature of the learning activities resonates with the one item on the Likert survey on which the control group rated themselves higher. They were more likely to have a positive response to the prompt “I did my best to engage with all of the activities designed to help me learn the scientific terms for this unit.”

In contrast with this, the intervention group seems to have benefitted from the collaborative nature of these learning activities. In the word cloud shown in Figure 11, student responses emphasized words like “classmates,” “students,” “help,” “people,” and “questions.” These words indicate that the involvement of their peers was seen by students as a benefit. One student said “i [sic] was able to ask other students for help when I didn't understand something, which is very good …” while another responded, “I liked the collaboration with fellow students when we did the Powerpoint.” Several students mentioned the collaborative Google Slides on which their group work was shared as being beneficial. Indeed, the terms “notes,” “powerpoint,” and “slides” that appear prominently in the word cloud were used primarily as synonyms for the Google Slides when placed in context in student responses.

Unit Tests

The final data collection instrument was the classroom test that closed each unit of instruction. The scores for students on this test were separated based on the treatment group that the student represented, and the averages of the two groups were compared. Averages were very near one another for the two groups, with the overall average for the intervention group (*n*=14) at 81.14% being slightly lower than the average for the control group (*n*=15), which was 83.75%. Table 4 and Figure 12 below show the overall group mean for test scores, along with the standard deviation and standard error for each group.

Table 4. Group mean test scores, standard deviation, and standard error for the two tests used during the investigative period, shown for control and intervention groups, and for the whole group.

Group	Mean	Standard Deviation	Standard Error
Control	83.75	11.13	2.87
Intervention	81.14	14.40	3.85
Whole Group	82.58	12.66	2.31

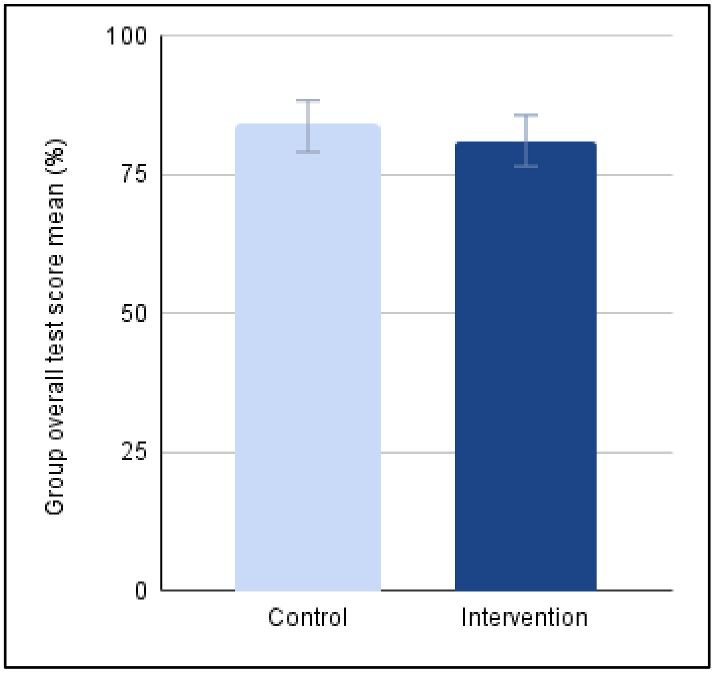

Figure 12. Group mean test scores for both tests used during the investigative period.

Analysis of this data is useful for answering the third and final focus question for this action research project, How is vocabulary acquisition related to general science performance in my classroom? This data point alone would seem to show that the intervention group performed slightly more poorly. Recall that the intervention group performed better on the vocabulary posttests for both units. This would point toward a negative association between vocabulary performance and boarder performance on classroom tests. However, the single point of comparison does not give enough data to make strong conclusions, especially because the difference were small. Because there is no trend, like was present in the Likert survey, to draw even tentative conclusions from small, another method comparing performance on vocabulary and general assessments was needed. The method used in this case was a linear regression performed on the performances of individual students, comparing average vocabulary assessment performance and classroom test performance. Figure 13, below, shows this regression.

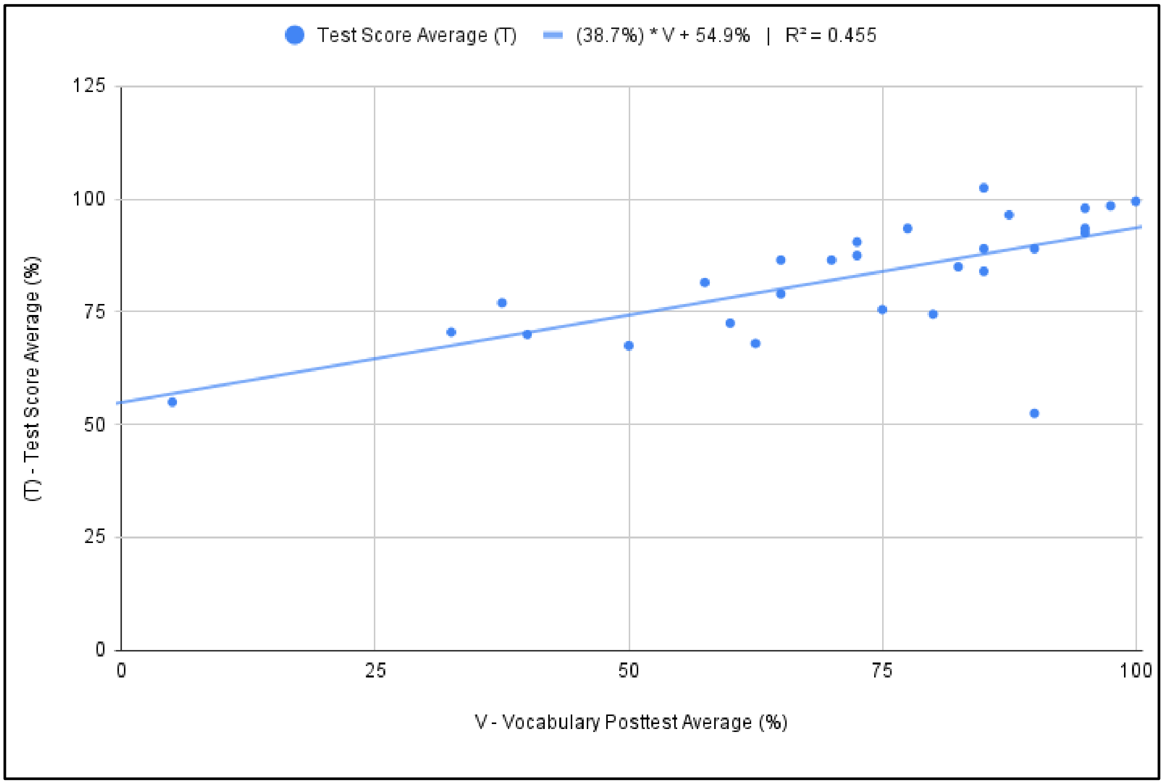

Figure 13. Unit test score mean versus vocabulary posttest mean.

CHAPTER FIVE

CLAIM, EVIDENCE, AND REASONING

Claims From the Study

Claim 1: Intervention Learning Activities Increase Vocabulary Learning More Than Control Activities

The higher normalized gain and slightly more positive response to prompts indicating confidence shown by students in the intervention group indicated a higher level of learning for these students than students in the control group. Students in the intervention group had lower pretest scores, with the intervention group having an average of 5.40 correct while the control group had an average of 6.97 correct responses out of 20. The intervention group also had higher posttest scores of 14.92 for the intervention group versus 13.27 for the control group. This resulted in larger normalized gains of <g>=0.653 for the intervention versus <g>=0.483 for the control group. Both groups showed gains in the range considered “medium gain,” $0.3 < g < 0.7$ (Hake 1998). However, the intervention group was near the top of the medium range, near the range considered “high gain.” Student survey responses showed slightly more positive responses to confidence as well. Fifty percent of students indicated “Agree” or “Strongly Agree” to the prompt regarding being prepared for the test in the intervention group, versus 47% for the control group. Intervention groups also had fewer negative responses to confidence related prompts. For the same prompt, only 29% indicated “Disagree” or “Strongly Disagree” in the intervention group versus 47% in the control group who had one of these negative responses.

This outcome matches what was expected based on Motivation Theory, Schema and Psycholinguistic Theories, and Sociocultural Theories. The intervention activities involved collaboration, and involved students collaboratively developing definitions and resources, which leveraged the Sociocultural Theories and the collaborative aspect of learning. This matches the findings summarized in the meta-analysis by Moody et al. “Collaborative scaffolding, such as within discussions, fosters multidimensional, world knowledge that goes beyond ability to recall meanings (Moody et al., 2018, p. 10). The use of graphic organizers, and the inclusion of visuals in the Quizlet used by students in the intervention group leveraged the Dual Coding, and the Schema and Psycholinguistic Theories, and the praise given to students who had completed the recommended 15 min/day reviewing leveraged the Motivation Theory influence on learning, since Moody et al. summarized that “Tenets of motivation theory include the use of rewards, competition, and the generation of student interest” (Moody et al., 2018, p. 11).

Claim 2: Students had slightly more positive subjective responses to intervention activities than they did to control activities

Responses by students in the intervention group to surveys showed a consistent pattern of slightly more positive responses, on both the Likert survey and the open-ended survey. The slightly more positive response and less negative response to questions about confidence was previously described, but similar patterns showed up when students were asked if they or their classmates enjoyed the learning activities. Although no group had a majority of responses that were positive (“Agree” or “Strongly Agree”) to either question about enjoyment, the intervention group had a higher minority of positive responses. In the intervention group, 50% indicated a positive response regarding whether they enjoyed the learning activities, although only 14% would venture to suggest enjoyment on the part of their classmates. For the control group, only 33% had positive responses indicating that they enjoyed the activities, and only 20% had positive responses on behalf of their classmates. When examining the negative responses, the same pattern shows. For the intervention group, more students had negative responses to the prompt about them enjoying the learning activities, but for the control group, all of the negative responses indicated "Strongly Disagree" to the prompt. Considering the enjoyment of their classmates, fewer students in the intervention group, 14%, had negative responses than in the control group, 27%.

Although any conclusions taken from it must be considered tentative, the open-ended survey matched the patterns seen in the Likert survey. Many of the students in responses from the control group indicated a focus on a task-oriented mindset. In addition to words mentioned earlier, words like "definitions," "work," "study," and "long" were prominent in their responses. Add to that the single prompt on the Likert survey that had a more positive response for the control group being focused on "I did my best…" and we begin to see that the mindset of students in the control group was very much extrinsically focused. Control group students responding to this prompt had the highest numerical average (4.5) for any item on the Likert survey, and the highest percentage of positive responses. 83% of control group students indicated that they "Agree" or "Strongly Agree" with this statement, which is distinctly higher than the 60% for the intervention group.

Motivation Theory can provide some explanation for the focus on external results that seemed to characterize the mindset of students in the control group. Many of the students at our school have adopted a strong desire to achieve academic success, and many of them connect effort with success. However, this extrinsic motivation was not stronger than the combination of factors that produced positive responses for the intervention group. These students were able to involve the social and collaborative aspects of their minds in addition to the motivation to succeed when engaged in the intervention learning activities. I attribute the narrowness of the margin in the responses of the two groups on the Likert survey to the fact that the rest of the course involves many opportunities for collaborative social learning activities and for engaging the students' abstract thinking as described in the Dual Coding and Schema and Psycholinguistic Theories.

Claim 3: Vocabulary learning is strongly associated with general science performance in my classroom

Comparison of student performance based on vocabulary posttest scores and classroom unit test scores showed a strong correlation. Figure 13, the linear regression shows this connection. Viewed in this way, the connection between vocabulary performance and test performance seems clearly to be a positive one. The line of best fit modeling test scores using this linear regression could be stated as: Test Score = (39%) *(Vocabulary Posttest) + 55%. This relationship has a coefficient of determination of $R^2 = 0.455$, meaning that this analysis predicts that approximately 46% of the difference in test scores could be determined by the difference in vocabulary posttest scores.

I consider the linear regression analysis, which takes into account individual student performances, to have more explanatory power than comparison of a single mean for each group. Taken together the data from the test scores and the vocabulary scores is claimed to have provide enough evidence to suggest that vocabulary performance has a strong positive relationship with overall class performance in my science class.

This comports well with my informal assessment of my class in the past, and with the predictions from the literature. As noted in the conceptual framework, Seifert and Espin (2012), Ardasheva and Tretter (2015), and Groves (2016), among many others, noted that science courses require a strong commitment to learning subject-specific vocabulary, and that failure to learn this vocabulary is strongly associated with poor performance in science courses generally. It is instructive to have specifics for my own course, at least for these two units, describing just how strong the impact of vocabulary learning really is.

Value of the Study and Consideration for Future Research

Confirming the impact of vocabulary learning on general science performance specific to my classroom has been helpful. Now that I have confirmation of some effective techniques for vocabulary learning in my class, I will be able to more wisely allocate student time and class time. It was especially helpful to find techniques that students identified as less burdensome, and which they seemed slightly to prefer but which were nevertheless more impactful on their learning.

In the future, I would like to conduct more learning from my students about what is effective for them. I learned about the usefulness of Quizlet from the fact that many of the students take the time to make study sets on Quizlet on their own. I'm happy to leverage this tool in all my units moving forward. However, I'd love to know what other tools they find helpful.

I am also interested in finding ways to decrease the amount of burdensome work that students need to do. Although it is probably inevitable that there is some work that is important and helpful, but not enjoyable, I'd like to find the "minimum effective dose" of this kind of work. Anecdotally, students indicated that they spent less time on the intervention learning activities than they did on the control learning activities. I'd love to find more task replacements like this that decrease the burden on students. One of the tasks that takes up a significant minority of our class time is focusing on specific questions and using resources and collaboration to find answers. These usually take the form of questions from the text or worksheets. Although I suspect that some work like this might be necessary, neither students nor I enjoy it nearly as much as time in the lab being involved in the scientific process. Finding the correlation between time engaged in activities like this and general class performance might allow me to find the minimum effective amount of time that would be necessary to devote to tasks like that without decreasing overall performance.

Impact of Action Research on the Author

This action research project has been a wonderful opportunity to learn more about the methods that are helpful for my students in their learning process. Action research was a great ingredient in my professional development since it allowed me to connect the learning theories to my own classroom and my own students. This action research project was helpful for me since it added a helpful tool that I can implement to improve vocabulary instruction. Although vocabulary instruction might be thought of as old fashioned or no longer worth emphasizing, a well-developed vocabulary is an important prerequisite for effective communication. This investigation confirmed my suspicions that vocabulary acquisition was important for broader success in my class and helped me understand some ways that students can grow their vocabulary more effectively. Additionally, this study has impressed upon my thinking the value of student collaboration. One quote impressed me and reminded me of the important role of collaboration in learning. A student gave this response on the open-ended survey. “I liked how we worked in groups it really helped me understand more, especially if it comes out of my peers mouth it helps me remember it more.” Although it is never far from my mind, it is always useful to have students bring to the front of my mind the idea that part of my job is to listen to them and learn from them what will be effective in helping them develop their knowledge and skills.

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APPENDICES

APPENDIX A

MONTANA STATE UNIVERSITY’S INSTITUTIONAL REVIEW BOARD COMPLIANCE

Beiswanger, Kelly <kelly.beiswanger@montana.edu>
to me, Jessica

Thu, Jan 27, 5:43 PM

Dear John,

Thank you for your application. This email acknowledges receipt of the request for IRB Review and serves as the Approval Letter for your research. Your new **IRB Exempt Protocol # is JA012722-EX**.

Study Title: **THE IMPACT OF VOCABULARY INSTRUCTION ON SCIENCE LEARNING IN SECONDARY A SCIENCE COURSE**

As the PI, it is your responsibility to facilitate subject understanding by informing subjects of all aspects of the project, providing an opportunity to ask questions, and describing risks and benefits of participation. Submit any new changes to the research protocol to the IRB via Amendment Form prior to implementing.

The research described in your submission is exempt from the requirement of additional review by the Institutional Review Board in accordance with 45 CFR 690.104(d). The specific paragraph which applies to your research is:

> (1) Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Thank you,
Kelly Beiswanger

IRB Administrator & Program Manager
Office of Research Compliance
Hamilton Hall 114
Montana State University
kelly.beiswanger@montana.edu

APPENDIX B

VOCABULARY PRE- POSTTEST | GENETICS

1. allele	2. epistasis	3. homologous	4. p generation
5. chromatid	6. f1 generation	7. homozygous	8. pedigree
9. chromosome	10. f2 generation	11. hybrid	12. phenotype
13. codominant	14. gene	15. incomplete dominance	16. pleiotropy
17. dihybrid	18. genotype	19. karyotype	20. polygenic
21. diploid	22. haploid	23. monohybrid	24. recessive
25. dominant	26. heterozygous	27. mutation	28. sex-linked

Write in the blank the number corresponding to the word from the list above that best answers these questions or completes these statements. No word will be used more than once, but some words will not be used at all.

1. ____________ The location on a chromosome where the information for a particular trait is stored
2. ____________ The alternate forms in which a gene can be expressed
3. ____________ The true-breeding organisms used in the first step of a genetic experiment like the ones conducted by Mendel
4. ____________ A visual representation of all the chromosomes for an organism, arranged in pairs based on length and staining pattern.
5. ____________ The information about which alleles are present in a cell, normally represented by two letters.
6. ____________ Traits that only show up when no different alleles are present
7. ____________ Traits that always show up when they are present
8. ____________ Genes that are present on the X chromosome
9. ____________ The genetic condition where two different alleles are present for a characteristic in the same cell
10. ____________ The observable effect of a gene, often influencing the physical appearance of the individual
11. ____________ A cell with two copies of the genome
12. ____________ One half of a duplicated chromosome
13. ____________ An individual whose parents had different versions of a particular gene
14. ____________ A condition where two alleles are both completely expressed, like in roan horses
15. ____________ The genetic condition where both alleles for a characteristic are the same
16. ____________ A cell with only one copy of the genome
17. ____________ A cross where two different characteristics are considered
18. ____________ A cross where only one characteristic is considered
19. ____________ The two chromosomes that have information about the same characteristics on them.

20. ____________ In Mendel's experiments, these would have represented the grandchildren of the true-breeding plant. They showed the 3:1 ratio that he observed.

APPENDIX C

VOCABULARY PRE- POSTTEST | DNA - PROTEINS

1. adenine	2. double helix	3. nitrogenous base	4. ribosome
5. amino acid	6. exon	7. nucleic acid	8. single helix
9. anticodon	10. guanine	11. nucleotide	12. thymine
13. codon	14. helicase	15. Okazaki fragment	16. transcription
17. cytosine	18. histone	19. polymerase	20. translation
21. deoxyribose	22. intron	23. replication	24. tRNA
25. DNA	26. mRNA	27. ribose	28. uracil

Write in the blank the number corresponding to the word from the list above that best answers these questions or completes these statements. No word will be used more than once, but some words will not be used at all.

1. ____________ The combination of a nitrogenous base, a sugar, and a phosphate group
2. ____________ The sections of DNA formed on the lagging strand during replication
3. ____________ The molecule that stores information for how to build all of a cell's proteins
4. ____________ A building block of a protein that is connected to make proteins by peptide bonds
5. ____________ The process of copying DNA
6. ____________ The molecule that gets formed at the end of the process of transcription
7. ____________ The shape of a DNA molecule
8. ____________ The DNA base that pairs with cytosine
9. ____________ The enzyme that adds more nucleotides onto a growing strand of DNA or RNA
10. ____________ The sugar found in RNA molecules
11. ____________ A set of three nucleotides that specify a single amino acid
12. ____________ A section of DNA that does not end up choosing amino acids: this section is removed by splicing before a mature RNA molecule forms
13. ____________ The process that involves information from RNA being used to make proteins
14. ____________ The enzyme that unwinds and unzips a DNA molecule to prepare it to be read
15. ____________ The nitrogenous base that is found in RNA but not in DNA
16. ____________ The proteins around which DNA is wound to keep it from tangling
17. ____________ The category of organic molecule that includes both DNA and RNA
18. ____________ This sugar is found in DNA molecules, but not RNA molecules
19. ____________ If an adenine base is present in a DNA molecule, the corresponding spot will be occupied by this base after transcription
20. ____________ This molecule has an anticodon at one end, and a section for attaching to a specific amino acid at the other end

APPENDIX D

STUDENT OPINION SURVEY | SCIENTIFIC TERMS

Participation in this survey is voluntary and will not impact your grade.

Indicate if you participated in the traditional vocabulary learning activities or the new vocabulary learning activities for this unit.

______ Traditional vocabulary learning activities
______ New vocabulary learning activities

Indicate the degree to which you agree or disagree with each statement, using the following scale:

1 = Strongly Disagree
2 = Disagree
3 = Neither agree nor disagree
4 = Agree
5 = Strongly agree

1. ______ I feel confident in my ability to understand the scientific terms used in this unit.
2. ______ I enjoyed the activities that I participated in to learn the scientific terms for this unit.
3. ______ I did my best to engage with all of the activities designed to help me learn the scientific terms for this unit.
4. ______ I could talk about this unit with a student and help them understand the scientific terms we used in this unit.
5. ______ I feel prepared for the test on this unit.
6. ______ My classmates that did the same kind of learning activities for scientific terms for this unit enjoyed learning this way.
7. ______ I would recommend that future classes learn vocabulary using the same type of learning activities as I used for this unit.

APPENDIX E

OPEN-ENDED STUDENT SURVEY | SCIENTIFIC TERMS

Participation in this survey is voluntary and will not impact your grade.

1. What are some of the things that you enjoyed most about the activities designed to help you learn scientific terms for this unit?

2. What are some of the things that seemed most helpful to you in learning scientific terms for this unit?

3. What are some of the things that you enjoyed least about the activities designed to help you learn scientific terms for this unit?

4. What are some of the things that seemed most unhelpful to you in learning scientific terms for this unit?