

EFFECTS OF USING VOCABULARY STRATEGIES WITH HIGH SCHOOL STUDENTS
ON SCIENCE CONTENT-BASED ASSESSMENTS

by

Kara Lynn Fewlass

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DEDICATION

Without support from my family, this amazing journey would not have been possible. My sister, Teresa, continuously provided encouragement and had a keen eye proofreading my work. My partner, Jay, had endless patience when I asked for help with building ant farms, seined the river and filled the dining room table with data collection efforts, course after course. My mom, Terri, and children, Andrew and Emily, took care of all the ins and outs of our daily life while I worked on my capstone. I am so thankful for all their help.

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TABLE OF CONTENTS

INTRODUCTION AND BACKGROUND.....	1
Context of the Study	1
Focus Statement/Question	3
CONCEPTUAL FRAMEWORK.....	4
Review of Vocabulary Strategies	4
Frayer Model.....	4
Word Games.....	8
Word Wall	10
Summary	12
METHODOLOGY	14
Demographics	14
Treatment	15
Data Collection and Analysis Strategies	17
DATA ANALYSIS: CLAIMS AND EVIDENCE.....	23
Results.....	24
VALUE: REASONING AND REFLECTION	34
Claims from the Study	34
Value of the Study and Consideration for Future Research	34
Impact of Action Research on the Author	38
REFERENCES CITED.....	41
APPENDICES	45
APPENDIX A: IRB APPROVAL.....	46
APPENDIX B: VALENCE ELECTRON AND LEWIS DOT PRODUCT	48
APPENDIX C: VALENCE ELECTRON AND LEWIS DOT VOCABULARY MATRIX.....	52
APPENDIX D: BONDING PRODUCT: COVALENT AND IONIC	54
APPENDIX E PRE BONDING FRAYER MODEL LIKERT SCALE	58
APPENDIX F BONDING FRAYER MODEL	61
APPENDIX G POST BONDING FRAYER MODEL LIKERT SCALE.....	63
APPENDIX H: CO-TEACHER OBSERVATION FORM	66

TABLE OF CONTENTS CONTINUED

APPENDIX I: CO-TEACHER BONDING FRAYER MODEL INTERVIEW.....	68
APPENDIX J: PERIODIC TRENDS PRODUCT	71
APPENDIX K: ELECTRONEGATIVITY PRODUCT	75
APPENDIX L: PRE ELECTRONEGATIVITY INTERACTIVE WORD WALL LIKERT SCALE	79
APPENDIX M: POST ELECTRONEGATIVITY INTERACTIVE WORD WALL LIKERT SCALE	81
APPENDIX N: CO-TEACHER ELECTRONEGATIVITY INTERACTIVE WORD WALL INTERVIEW	83
APPENDIX O: BALANCING EQUATIONS PRODUCT	86
APPENDIX P: CHEMICAL REACTIONS PRODUCT.....	89
APPENDIX Q: PRE CHEMICAL REACTIONS GAMES LIKERT SCALE.....	93
APPENDIX R: POST CHEMICAL REACTIONS GAMES LIKERT SCALE.....	95
APPENDIX S: TEACHER OBSERVATION FORM-GAMES	97

LIST OF TABLES

Table	Page
1. Table 1. Data Triangulation Matrix.....	22
2. Table 2. A basic matrix asking students for definitions and images.	53
3. Table 3. A data collection tool for monitoring vocabulary use in writing and discourse.....	67
4. Table 4. Data set for 5.6.7	91
5. Table 5. Teachers' observations of student behavior will be entered on this form.....	98

LIST OF FIGURES

Figure	Page
1. Figure 1. Smyrna High School, taken by K. Fewlass (2025).	1
2. Figure 2. A Frayer model that I created for my Earth Science class illustrates the example of stratigraphic layers vs a nonexample of weathered sandstone.	5
3. Figure 3. The elementary level word wall is a visual reference to help students remember correct terminology and spelling.	19
4. Figure 4. Students made their own connections between terms and content while working in small groups to create interactive word walls.....	20
5. Figure 5. Student perception that Frayer models were more effective than a vocabulary matrix for learning vocabulary terms and connections between terms, pre and posttreatment, ($n=18$).....	24
6. Figure 6. Student perceptions of Frayer models impacting quiz grades, pre and posttreatment, ($n=15$).	25
7. Figure 7. Student perceptions of using an interactive word wall to understand key terms and the connections between them, ($n=20$).	26
8. Figure 8. Use of an interactive word wall had a greater impact on student grades compared to an elementary level word wall, pre and post treatments, ($n=20$).	27
9. Figure 9. Students' perceptions of effectiveness of using paper and computer-based games, pre and posttreatment responses, ($n=20$).....	28
10. Figure 10. Survey responses for student perception of whether using games for review had an impact on their grade, pre and posttreatment, ($n=20$).....	29
11. Figure 11. An overall comparison between normalized gain scores indicated that the basic vocabulary matrix was the most effective strategy based on student growth between pretest and posttest scores with a gain of 0.776.	31

LIST OF FIGURES CONTINUED

Figure	Page
12. Figure 12. Survey responses indicated that all students perceived that the Frayer model and interactive word wall helped them understand vocabulary terms and make connections.	32
13. Figure 13. Student survey responses to the statement indicate that the Frayer model had the most impact on student grades.	33
14. Figure 14. The portion of the organizer that describes parts of a volcano are in matrix format while the specific types of volcanoes are in Frayer model format	36
15. Figure 15. The cat has paws, a word that has a sound similar to the term positive. Cations, or in this example, cat ions, have positive, or paws itive, charges.	39
16. Figure 16. The IRB approved consent form completed November 19, 2025.....	47
17. Figure 17. Core shielding analogies compare to an elephant family and football players.....	50
18. Figure 18. A segment of the periodic table provided for student reference.....	51
19. Figure 19. Students select the incorrect isomer and explain why it is incorrect.	57
20. Figure 20. A blank Frayer model.	59
21. Figure 21. A visual reminder of what the students' vocabulary matrix should look like.....	59
22. Figure 22. A blank ionic bond Frayer model.	62
23. Figure 23. A completed ionic bond Frayer model.....	62
24. Figure 24. A completed Frayer model for visual reference.	64
25. Figure 25. A complete matrix for visual reference.	64

LIST OF FIGURES CONTINUED

Figure	Page
26. Figures 26. A Frayer model and matrix are shown as comparison_	69
27. Figure 27. A graph showing the intercept of atomic radius and number increase.	73
28. Figure 28. Atomic radius decreases as you go left to right across periods.	74
29. Figure 29. Effective nuclear charge increases as you go left to right across the periods.	74
30. Figure 30. The dipole bond for water showing Oxygen has more energy.	76
31. Figure 31. The polar bear is pulling the penguin.	77
32. Figure 32. The Allen scale.	78
33. Figure 33. The polarity scale.....	78
34. Figure 34. Stick figures represent the relationship between compounds in a chemical reaction.	90
35. Figure 35. Stick figures represent the exchange of elements on both sides of the equation.....	90
36. Figure 36. A fish cooking on a grill with steam being produced	92

ABSTRACT

As an effort to help myself meet my professional development goal of measuring student growth on content-based assessments while focusing on correct usage of scientific terms, I investigated the effects of using vocabulary strategies with 20 9th grade high school students. Pre and posttest scores were compared to provide quantitative data. Likert scale surveys also provided quantitative data by assessing student perception of strategy effectiveness and potential impact on their grade. Co-teacher interviews and teacher observations provided qualitative data. The first nontreatment to treatment comparison was between a vocabulary matrix in the valence electron unit and Frayer models in the bonding unit. Both strategies included defining and drawing images of key terms, but students also identified examples and non-examples of key terms on the Frayer models. Students' academic achievement decreased although data obtained from both students and the co-teacher reflected that Frayer models were valued as a vocabulary strategy that they would like to use again. The second non-treatment to treatment comparison was between student use of an elementary word wall for the periodic trends unit and student use of interactive word walls they created for the electronegativity unit. Teacher assigned student groups used sets of term and image cards to create concept connections. Student and co-teacher responses for using an interactive word wall were positive. The third comparison focused on the non-treatment balancing equations unit and treatment unit in which paper and computer-based games reinforced chemical reactions key terms. Data from game use showed no statistical improvement in academic achievement while student perceptions of engagement and effectiveness decreased. Overall results indicated that use of interactive word walls was the most effective vocabulary strategy for improving student comprehension on science content-based assessments.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

My school is Smyrna High School (SHS) located in Smyrna, Delaware. The first high school class graduated in 1894 and until the mid-1990's, Smyrna was considered a farm community. The high school building was built in 1970 and home to about 800 students, grades 9 to 12, with the capacity to house 2,000 students (Everything Explained, 2025) (Figure 1).



Figure 1. Smyrna High School, taken by K. Fewlass (2025).

Since 2017, the Smyrna community has expanded rapidly and continues to enthusiastically support the I Love Smyrna School District Day and homecoming. SHS is now considered a suburban school, home to 1,790 students, with a 49% minority population (U.S. News, 2025). SHS is a Title 1 school with 34% of students receiving free and reduced lunches (Delaware Department of Education, 2025; Girton, 2025). Twenty-four percent of SHS students

have individualized education plans (IEPs) (Carrow, 2025). College Readiness scores for SHS students were reported at 19.8% with proficiency skills in reading skills being 46%. Students had math proficiency scores of 22% and proficiency scores of 21% in science. (U.S. News, 2025). Having been employed as a high school science teacher at SHS for seven years, I have taught geology, SAT preparation and all academic levels of physical science. My professional development is determined by the Delaware Teacher Growth and Support System. From options provided by Delaware Department of Education (2025) designed to encourage me to improve my practice, I selected to measure student growth on content-based assessments while focusing on correct usage of scientific terms. Results are determined by measuring normalized gain between pretest and posttest content-based assessments on content taught within a six-week period. I interpreted this goal as meaning that I should be teaching students how to use vocabulary strategies as we work through our lessons to help them improve their word recognition skills and use of appropriate terminology on posttests. To help students learn vocabulary strategies, I previously implemented vocabulary matrix assignments that include the term, definition, and an image. I included these terms on an elementary level word wall for students to reference the terms after we learned them. Students referenced these matrix and word wall tools for matching and defining type questions but did not appear to be using the tools to include scientific terms in their writing or discourse. To help my students clarify concepts, make connections to other content and demonstrate higher level learning skills, the use of vocabulary matrixes will extend to utilizing Frayer models. Frayer models ask students to identify non examples and specific examples. The elementary level word wall will be replaced with an interactive word wall to reinforce students' relationships between term, definition, image or diagram and connections to

other terms found in the same unit of study. Vocabulary games will be utilized to further engage students in word recognition activities. These strategies will help students increase their scores on proficiency assessments, meet my professional development requirements and provide me with more effective strategies to meet Individualized Education Plan (IEP) accommodations.

Focus Question

My focus question was, What are the effects of using vocabulary strategies with high school students on science content-based assessments?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Review of Vocabulary Strategies

According to Hazar (2020) it is impossible to communicate, read, write and speak effectively without knowledge of appropriate vocabulary. Students need to be able to recognize and define vocabulary terms to create meaningful statements. Focusing on vocabulary allows students to understand and make connections to new concepts (Cohen, 2010). In science classes, students with stronger scientific vocabulary are perceived by others to be more knowledgeable and have a stronger science identity (Pederson et al., 2022). Having stronger science identity increases students' confidence and initiative. Students need to use scientific terminology repeatedly to maintain and improve their comprehension and communication skills (Chen et al., 2020). Studies that I referenced assessed the use of Frayer models, word games and word walls with various age participants in different academic settings.

Frayer Model

Frayer models, designed by Dorothy Frayer in 1969, are used to improve student comprehension and word analysis skills (Cox, 2023). The Frayer model is an organizer that represents vocabulary terms in multiple ways to help students learn to analyze words. The organizer identifies the term, then has boxes for students to write in explanations. One box provides a place for students to create a definition in their own words. Other boxes may provide space for characteristics, examples, non-examples and images to help students connect to the meaning of the term (Figure 2).

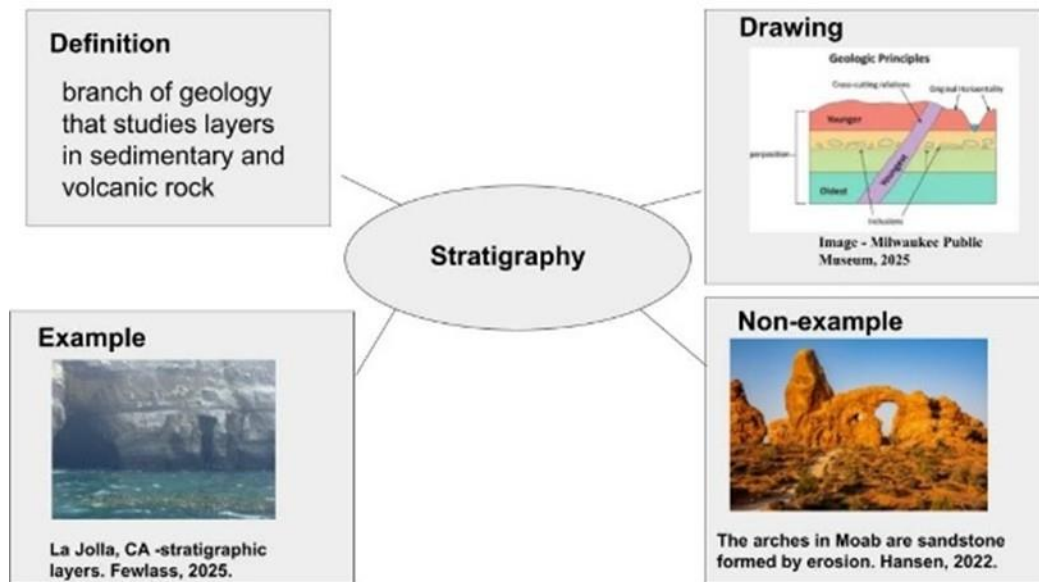


Figure 2. A Frayer model that I created for my Earth Science class illustrates the example of stratigraphic layers vs a nonexample of weathered sandstone.

Cox (2023) provided an example of a Frayer model for the term resistance. The model asked for definition, word family, visual representation and had a space for students to make further additional connections. According to Cox, a scaffold representing a higher thought process for the term resistance focused on identifying a relationship between the level of current and potential difference. The definition included what resistance is, how to measure it and units of measurement. The word family included similar words to resist that students may be more familiar with including resistor and resisting. The visual representation was an image of a battery illustrating the passage and resistance of electricity.

The use of Frayer models was assessed with three 6th-graders at a public intermediate school located in the midwestern United States by Harper (2022). Data was collected by comparing pretest and posttest scores, exit cards and a teacher reflection journal. Each student was representative of an ability group, including above grade level, grade level or

below grade level. Students completed and glued Frayer models into their notebooks, which they used on assessments. The Frayer model was selected as a vocabulary strategy because it addressed multiple learning styles including a visual representation, process of repetition and a hands-on aspect. Students were given a specific type of rock, such as schist or granite, as their vocabulary term. They used class discussion and short videos to create definitions, list characteristics, draw an image and label an example. Although the sample size was determined to be too small to use to establish significance, the benefits of multiple vocabulary learning strategies were stressed. Rosinski et al. (2017) emphasized that when students have a limited comprehension of content-based vocabulary, they cannot make complete connections to content, or they retain misconceptions.

When Frayer models were used with high school students, specifically 9th- and 10th-graders, a trend of increased posttest scores was evident. An English as a second language teacher at SMA Negeri 3 Pasarwajo, a public high school in Indonesia, observed from daily tests that 10th-grade students could not identify the meaning of vocabulary words from their text, although terms had already been defined using a dictionary in a previous lesson (Wati et al., 2022). Defining and translating terms did not improve long-term memory and students needed more conceptual understanding of vocabulary terminology. To help students improve their conceptual understanding of vocabulary, the Frayer model was selected as a vocabulary strategy tool. Tenth-grade students defined the term and identified specific features. They were also asked to compare examples and non-examples. The survey group included all the 10th-grade students who completed a 20-question multiple choice pretest and posttest. The treatment group consisted

of 21 students who used Frayer models to develop meanings for their vocabulary terms. When the posttest was given, treatment group scores increased by over 34 points (Wati et al., 2022).

In the Philippines, the test scores of 9th-grade students who were studying a chemistry unit were assessed to determine if there was a significant difference between scores on assessments of students who used Frayer models and those who did not (Sacapano & deCastor, 2022). Pretest scores showed no significant difference in the score between the groups of students. Both groups of 30 students had the same science teacher, but one group was taught using Frayer models. At the end of the unit, the treatment group had significantly higher scores on posttests than the nontreatment groups.

Like the previous 9th-grade studies, environmental science tests assessed in Louisiana showed an increase in posttest scores by students who used organizers including Frayer models (Buchanan, 2015). The 9th-graders were divided into three groups: two were treatment groups and one was a control group. All the students had the same teacher and were given the same pretest and posttest. Variables in teaching methodology included the usage of Frayer models by one treatment group while the second treatment group used a hierarchal model. The control group used guided notes with a PowerPoint. When observed, treatment groups using organizers appeared more engaged than students in control groups using guided notes. They were able to access interesting text and make additional connections to content while searching for higher-level content to complete statements on the organizers. The posttest scores of students in the treatment groups who used organizers were higher than those in the control group who used guided notes, which is consistent with observed results.

The results of these studies showed that students who used Frayer models attained higher posttest scores than students who used hierarchical models. The Frayer models addressed multiple learning strategies on one organizer format: reading and hands-on learning through drawing. Between the two treatment groups, use of the Frayer models increased conceptual understanding of vocabulary by including different characteristics and by having students identify an example of something that has opposite characteristics.

Word Games

Word games have been identified as a strategy to increase student motivation through friendly competition and in a relaxed atmosphere. Games can be created to address different levels of teaching vocabulary. Jannah et al. (2020) described the process of teaching vocabulary in three levels. The first level is the beginner level, in which students learn definitions of terms. Flash cards with terms on one side of the card and the definition on the opposite side are an appropriate strategy. The second level focuses on inductive reasoning skills with students using terms in sentences and in proper context. The third level is an appropriate expectation for high school students and focuses on students using vocabulary terms in both oral and written expression. A class of 32 students was observed and interviewed after participating in games for three days (Jannah et al., 2020). On the first day, students were divided into 11 groups with three to four students in each. Students were observed participating in relays, spinner games, memory games, and explaining answers for true or false questions. The second day of observations focused on student speaking skills. Students were divided into seven groups. The game was like a spelling bee, with a single representative from each group spelling a provided word at a given time. The next representative student had to provide a meaning for the word spelled by the

preceding student. The games the students played on the third day were digital. During observations, students appeared to be more engaged than in previous observations. Students provided qualitative responses of having felt more active and found new ways to convey their vocabulary terms when interviewed. Vocabulary tests assessed by a rubric were given to 10 students. There was no explanation as to why only 10 students participated in the test. The results yielded a mean average of 87.2%, meeting expectations of very high scores (Jannah et al., 2020).

Digital games were identified as a learning strategy to engage students through the inclusion of animated graphics and achieving goals while progressing through terminology practice (Hazar, 2020). Two heterogeneous groups of 8- and 9-year-old students were identified by the classes they were enrolled in. The students attended English class for 80 minutes a week over a 4-month period. All students received content through traditional methodology including textbooks, audio recordings and worksheets. The identified variable was that one of the two groups utilized digital games. The digital games were loaded through the Education Informatics Network so teachers and students could access the games both in and out of school (Hazar, 2020). No data explaining if the games were accessed out of school was provided. Results were assessed from pretest and posttest improvement scores. Although these students were not in high school, the same pattern for test scores prevailed. Pretest scores between the groups showed no statistical difference. The experimental group posttest scores were statistically higher, demonstrating that digital games are an effective vocabulary strategy.

Li (2021) referenced the experimental comparison between mobile app vocabulary games and paper assessments on achievement levels of college students on the Chinese English Test Band 4 proficiency test. Two groups of 35 students were assessed. The students who had used the

game-based vocabulary strategies scored higher on the assessment. The author also noted that treatment group students were more motivated to study and appeared more self-confident. The results of these studies showed that students who had been engaged in academic games had higher scores on posttests than students who had not. Students of different academic levels in different settings were assessed after playing a variety of vocabulary-based games from paper-based matching activities to digital apps including Alphabet versus Aliens and Shanbay (Zou et al., 2018). Observations indicated a higher number of engaged students in classes where students were playing games.

Word Wall

Word walls are visual aids that provide students with immediate access to key words, correct spelling, and remain visible as students complete their content units (Kish, 2018). Word walls can be utilized in different ways. An elementary age group appropriate strategy includes adding words to the wall as they are taught. The words act as visual reminders and help with spelling. Sometimes words are organized by themes when students start new content. Terms organized by theme could be printed on colored paper to help students recognize the theme pattern. Most frequently in science classes, words are organized by content. Words should include pictures and definitions to improve comprehension for both lower-level and English Language Learner (ELL) students. Kish (2018) interviewed D. Pegrim, a first-grade teacher, and B. Crooks, a K-4 traveling special education teacher. Pegrim had a traditional word wall to which new vocabulary terms were added as they were learned. Pegrim also provided an alternate vocabulary strategy: having students create a book of most frequent words used when they write. Crooks did not have her own word wall but stated that she saw the benefits of word walls being

used in different ways as she travelled from class to class. Kish identified students as belonging to four groups based on academic achievement: above-grade-level, grade-level, below-grade-level and other. The group identified as other consisted of students who had diagnosed disabilities including autism, learning disorders, hearing and vision impairments, or a chronic illness. Pegrim stated that grade-level students received the most benefit from word walls where terms are added to the wall as they are mastered. Above-grade-level students find the word walls irrelevant because the terms are not challenging to them. Below-grade-level students should use word walls as a reference for spelling, but they need strong letter recognition skills to accomplish this. Kish recommended using activities to help below-grade-level students use word walls. Crooks stated that students with disabilities also need activities to help them use word walls because they tend to be unaware that they are supposed to look up at the wall and do not have the necessary letter recognition skills to spell.

Science word walls should not only include chapter or unit terms, but also terms that commonly appear throughout various science classes (Hooper & Harmon, 2015), such as measurements and root words. The root therm, meaning heat, was provided as an example. Root word examples include thermometer which measures heat and thermal pollution being heat pollution. Seeing terms and patterns repeatedly increases student comprehension over time. Interactive word walls promote scaffolding of concepts by providing a visual connection between scientific concepts and academic vocabulary (Jackson, 2018). Implementation of interactive word walls was selected to avoid students copying and memorizing terms in biology classes at a high school in Texas. Scores for Texas state biology exams were assessed to determine if interactive word walls could be considered effective vocabulary strategies. After

using these strategies, test scores for limited English language learners, economically disadvantaged and at-risk students increased. Graves' (2006) four-part approach to teaching vocabulary was referenced. This included language experiences, teaching individual words, word learning strategies and word consciousness. The key vocabulary words students were taught came from Texas State Science Standards. Vocabulary strategies included teaching students to identify root words, using prefixes, and making connections between Spanish and English words that had similar spellings, meanings or pronunciations. To create word consciousness, vocabulary words were represented by real objects or quality images. Language experiences were built by creating concept maps, including vocabulary terms illustrating categories, cycles, or hierarchies, to help students see patterns and make connections between vocabulary terms and concepts. Building language experience occurred with a hands-on approach when students helped construct a word wall. Students worked through a card sort of vocabulary terms, images and definitions. While some students shared their thoughts, a few other students created the interactive word wall by posting labeled laminated paper strips on the wall (Jackson, 2018).

Summary

Vocabulary strategies have been shown to increase student comprehension, evident through pretest and posttest assessments. Studies show that vocabulary strategies engaged students and encouraged them to make connections between the scientific term and other concepts, allowing students to demonstrate higher-level thinking skills. Repetitive use of vocabulary strategies reinforced the importance of terminology to students. Students need to be familiar with scientific terminology to reaffirm their knowledge of content while developing science literacy (Carrier, 2013). To develop language and word-based content, students need to

work with other students to learn to effectively share their thoughts and observations in written and oral expression. The use of correct scientific terminology promises to help students communicate more clearly.

CHAPTER THREE

METHODOLOGY

Demographics

This investigation focused on the effects of using vocabulary strategies on science content-based assessment with high school students, occurred during all my physical science classes that are 90 minutes long and rotate on odd and even days. I teach five of 47 team approach to mastery (TAM) classes at Smyrna High School (SHS) in Smyrna, Delaware (Duda, 2020; Semenik, 2025). TAM classes are the least restrictive environment for special education students where they are placed with regular education students and receive the same content (Duda, 2020). TAM classes have two teachers; I am the general education teacher and content expert and have a special education co-teacher, Colleen Skaggs, to help address student concerns and provide individual education plan (IEP) accommodations. My sample population of students is 20 9th-grade students, 10 of whom are special education students. Eight students are male and 12 are female. Fifty-five percent identify themselves as White on high stakes tests while 30% identify as Black including African American, African or African descent. The remaining 15% of students identify as Hispanic or mixed races with Hispanic origins. These students are not in the same class period; they are separated into six classes over the course of two days: odd and even days. These 20 students are the only ones who returned their parental consent forms required by the Smyrna School district.

Treatment

Research efforts took place over a 9-week period while students worked through their physical science chemistry units. Students focused on comprehension of Next Generation Science Standard (NGSS) physical science standards HS-PS1-1 and HS-PS1-2. Standard HS-PS1-1 emphasizes students being able to use the periodic table to determine properties of elements based on patterns of valence electrons in atoms (NGSS Lead States, 2013). The focus of this unit was valence electrons and Lewis dots. HS-PS1-2 indicates that students should be able to reference trends on the periodic table and properties of elements to explain simple chemical reactions (NGSS Lead States, 2013). The units of study that address this standard included bonding, periodic trends, electronegativity, balancing equations and chemical reactions.

The research methodology for this project received an exemption from Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A).

Students utilized vocabulary strategies to improve their comprehension of scientific terminology that appears in science content-based assessments. The first set of comparative strategies included in the valence electrons and Lewis dots and bonding units was the use of graphic organizers. The nontreatment strategy was a very basic vocabulary matrix that asked students to define key scientific terms and draw images illustrating main ideas. The treatment strategy, a Frayer model, occurred during the bonding unit. The Frayer model asked students to define terms, draw an image, provide an example and a nonexample related to the given term. An example is a concept that explains a student's interpretation of the key term. A nonexample is a concept that is content related and defines what the key term is not (Hanson, 2025).

The second set of comparative vocabulary strategies focused on the use of word walls and was included in the periodic trends and electronegativity units. In the periodic trend unit, terms from a vocabulary matrix organizer printed on paper strips that were posted on the wall to serve as visual reminders for usage and correct spelling. The elementary level word wall represented the nontreatment strategy while the treatment strategy was the interactive word wall which was utilized as a review activity in the electronegativity unit. Interactive word wall components included envelopes containing cards labeled with key terms, elements, and charts which students were expected to organize on a large poster paper. Organizational strategies included matching definitions with images and relationships between concepts.

The third set of comparative vocabulary strategies focused on the use of paper and computer-based games. The nontreatment was balancing equations unit which did not include the use of games. The chemical reactions unit included treatment strategies; paper- and computer-based games. The paper-based game challenged students to escape science class by gathering the correct clues for four stations. Correct clues were determined by correctly matching scientific terminology with definitions and concepts. The first station asked students to draw lines from terms on the left side of the paper to definitions on the right side of the paper. Letters were scattered in the middle of the paper that some of the matching lines crossed through. After all terms were matched with definitions, the letters in the middle of the paper that had lines crossing through them were unscrambled to form words. The word that matched one of the clues at the bottom of the page is recorded on the challenge answer card. The second station asked students to read statements and determine if the relationship between the vocabulary term and concept was true or false. If a statement was true, students colored a coin that represented the statement.

If the statement was false, students crossed off the corresponding coin. When all statements had been assessed, students calculated the sum of the coins to determine the correct clue. The third station provided eight multiple choice questions that asked for vocabulary terms to be matched with correct definitions and concepts. Each question had different letters representing answers. The clue was determined by matching a series of five correct letters with one of the three answer options provided. The fourth station asked students to reference a reading on Chemical reactions and to locate which paragraph seven statements were found in. Three potential clues were located at the bottom of the page focusing on statements not found in the paragraph. When all the stations had been completed correctly, students would successfully escape science class. The Fishing Frenzy Chemical Reactions Blooket was a computer-based video game where students earned points by demonstrating their knowledge of correct terminology by matching terms, definitions, images and examples while catching fish and other objects found in the ocean. The winner was the student who caught the most pounds of fish. (Smith, 2020; Fewlass, 2025).

Data Collection and Analysis Strategies

The purpose of this Action Research process was to determine the impact of using vocabulary strategies on science content-based assessments with high school students. All my students utilized the vocabulary strategies, but data was analyzed from a sample size of 20 students. The sample size ($N=20$) was determined by the number of students who returned signed consent forms. Student confidentiality was maintained by removing names and replacing them with random student numbers; Student 1, Student 2, etc. Additional identifying features including class periods and odd or even day were removed.

The first unit of study assessed was valence electrons and Lewis dots. Before students received any instructional content, they completed the Valence Electron and Lewis Dot Product, a pretest used to determine if they could make connections between previous content and new content or the level of knowledge that they already possessed on valence electrons and Lewis dots (Appendix B). The vocabulary strategy utilized in this unit was a traditional vocabulary matrix, the Valence Electron and Lewis Dot Vocabulary Matrix (Appendix C). Students completed the Valence Electron and Lewis Dot Product, a posttest, at the end of the valence electrons unit. Pre and posttreatment test scores were compared to determine normalized gain of improvement for each comparative unit. Low gains were less than .3 while medium gains were .3 to .7. High gains were greater than .7 (Hake, 1998). Normalized gain was determined to establish the overall average of what students learned compared to what they could have learned after students used each vocabulary strategy (McKagen et al., 2022).

Bonding was introduced to students with the content-based Bonding Product: Covalent and Ionic pretest (Appendix D). Frayer Model Likert Scale Surveys were given before the pretest and after the posttest to assess their anticipated thoughts on utilization and effectiveness of a new more detailed organizer, the Frayer model (Appendix E; Appendix F). Numerical values were assigned to each response so that median through use of the Wilcoxon Signed Rank test could determine if a statistical significance had occurred; p value $< .05$ (Statmate, 2026). Strongly agree was 4, agree was 3, disagree was 2 and strongly disagree was 1. The normalized gain between the pretest and posttest for both units was compared.

As students worked through lessons and had the opportunity to utilize the Frayer models, my co-teacher collected data using the Co-teacher Observation Form to determine which

students needed extra support in small groups. The Co-teacher Observation Form asked her to rate students' use of vocabulary strategies and correct terminology while speaking, reading and writing using values of 0 representing not at all, to 3 representing independently (Appendix H). Skaggs was interviewed using questions from Co-teacher Bonding Frayer Model Interview to provide me with her perception as another educator of student engagement while using the different organizers, the efficiency of each organizer and if the Frayer model would be a more useful tool to utilize in the future (Appendix I).

The next unit began with the Periodic Trends Product being given as a pretest and ended with the Periodic Trends Product being given as a posttest to compare normalized gain values (Appendix J). During the Periodic trends unit, terms that had been defined on a vocabulary matrix were printed on cards and intermittently added to an elementary level word wall, the nontreatment strategy, to reinforce terminology usage and correct spelling (Figure 3).

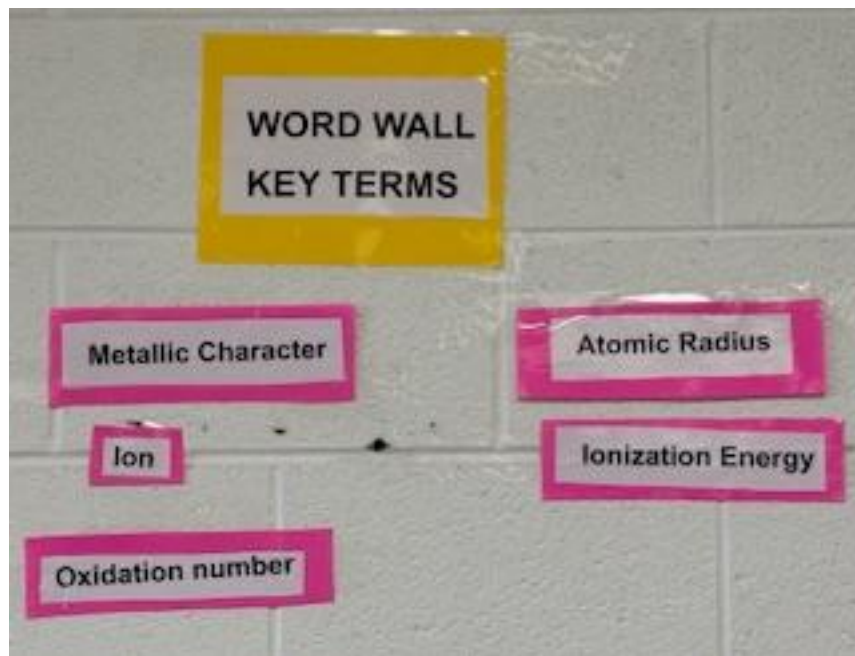


Figure 3. The elementary level word wall is a visual reference to help students remember correct terminology and spelling.

The electronegativity unit was the comparative treatment for word wall strategies. Students started the unit by completing the Electronegativity Product as a pretest and the Pre Electronegativity Interactive Word Wall Likert Scale Survey (Appendix K; Appendix L). The Electronegativity Product pretest was used to determine connections to prior knowledge while the Likert scale survey determined anticipated utilization and effectiveness of an interactive word wall. As a review activity before the posttest, students created an Electronegativity Interactive Word Wall focusing on relationships between vocabulary terms. Teacher assigned groups of two to three students received envelopes of content cards that they arranged on a large posterboard similarly to a collage. Students linked terms to images to reinforce basic concepts then identified higher level connections between basic concepts. The posters were taped to the walls to allow students to complete a gallery walk to compare conceptual organizers (Figure 4).



Figure 4. Students made their own connections between terms and content while working in small groups to create interactive word walls.

The Electronegativity Product was completed as a posttest so normalized gain between the pretest and posttest for both units could be compared to assess improvement scores impacted by use of word wall strategies. Following the Electronegativity Product, significance of student perceived use and effectiveness was calculated from the Post Electronegativity Interactive Word Wall Likert Scale Survey (Appendix M). Skaggs completed the Co-teacher Observation Form to determine which students needed extra support. She was interviewed using questions from the Co-teacher Electronegativity Interactive Word Wall Interview to gain her perceptions of student engagement while students created their interactive word walls to compare utilization of traditional compared to interactive word walls (Appendix N).

The third vocabulary strategy that was included in this investigation focused on the use of content related games. The balancing equations unit was the no game usage control group in which students were assessed for normalized gain by completing the Balancing Equations Product as a pretest and posttest (Appendix O). The chemical reactions unit was the treatment group utilizing both paper-based and computer-based games. Students began the chemical reactions unit with the Chemical Reactions Product being given as a pretest to determine the amount of their prior knowledge and Pre Chemical Reactions Games Likert Scale survey that assessed students' interest in playing content-related games and expectations for usefulness (Appendix P; Appendix Q). During the chemical reactions unit of study, teacher assigned pairs of students completed the paper-based Chemical Reactions Escape Room (Smith, 2020). Individually, students completed the Fishing Frenzy Chemical Reactions Blooket (Fewlass, 2025).

Students were given the Chemical Reactions Product as a posttest to assess mean of normalized gain for improvement scores after utilizing vocabulary-based games. Students were also given the Post Chemical Reactions Games Likert Scale Survey to determine if a significant change in students' perceptions on effectiveness and engagement had occurred (Appendix R). I recorded observations using the Teacher Observation Form-Games to assess student engagement, use of correct terminology while speaking and writing and whether students corrected errors (Appendix S). Interpretation of these data sources offered a triangulated understanding of the effects of using vocabulary strategies on science content-based assessments with high school students. The data also provided insight into the types of vocabulary strategies preferred by students. Observations of student engagement and effectiveness taken by a high school special education science teacher were documented and assessed (Table 1).

Table 1. Data Triangulation Matrix.

Focus Question	Data Source 1	Data Source 2	Data Source 3	Data Source 4
What are the effects of using vocabulary strategies with high school students on science content-based assessments?	Pre and posttreatment quizzes to determine normalized gain	Pre and posttreatment Likert Scale surveys	Co-teacher Interviews	Teacher observations

CHAPTER FOUR

DATA ANALYSIS: CLAIMS AND EVIDENCE

Results

Results showed some vocabulary strategies improved students' scores on science content-based assessments and others did not. Data also showed that students perceived some of these strategies to be beneficial to their learning and achievement and others not to be. Normalized gain was lower on quizzes where students had used Frayer models than on quizzes where students used matrices. Student survey responses indicated that students felt Frayer models were more effective at helping them comprehend vocabulary than matrices. Student use of interactive word walls resulted in a significant difference between posttreatment quiz scores when compared to elementary word wall use. While the survey responses for the previous vocabulary strategies reflected students having positive perceptions about effectiveness, they did not have positive perceptions of game use, even though pre and posttreatment quiz scores had high normalized gains.

Frayer Model

The nontreatment unit utilized a basic vocabulary matrix and had a high normalized gain of .776 between pre and posttest (Hake, 1998). The treatment unit utilized Frayer models for vocabulary terms and resulted in a medium normalized gain, .517. Figure 5 illustrates survey responses regarding visualizing the Frayer model as a vocabulary tool. Eighteen pretreatment surveys were analyzed; one student submitted a survey with no responses, and another submitted a response with more than one answer selected for multiple questions. Pre and posttreatment

surveys indicated students' perceptions about the effectiveness of Frayer models significantly increased. Pretreatment survey responses indicated 89% agreed using a Frayer model would help them understand content and 11% disagreed/strongly disagreed. Posttreatment responses increased to 100% strongly agreed/agreed. The Wilcoxon Signed Rank test indicated a significant increase in agreement from pretreatment ($Mdn=3$) to posttreatment responses ($Mdn=3.5$), $p = 0.036$.

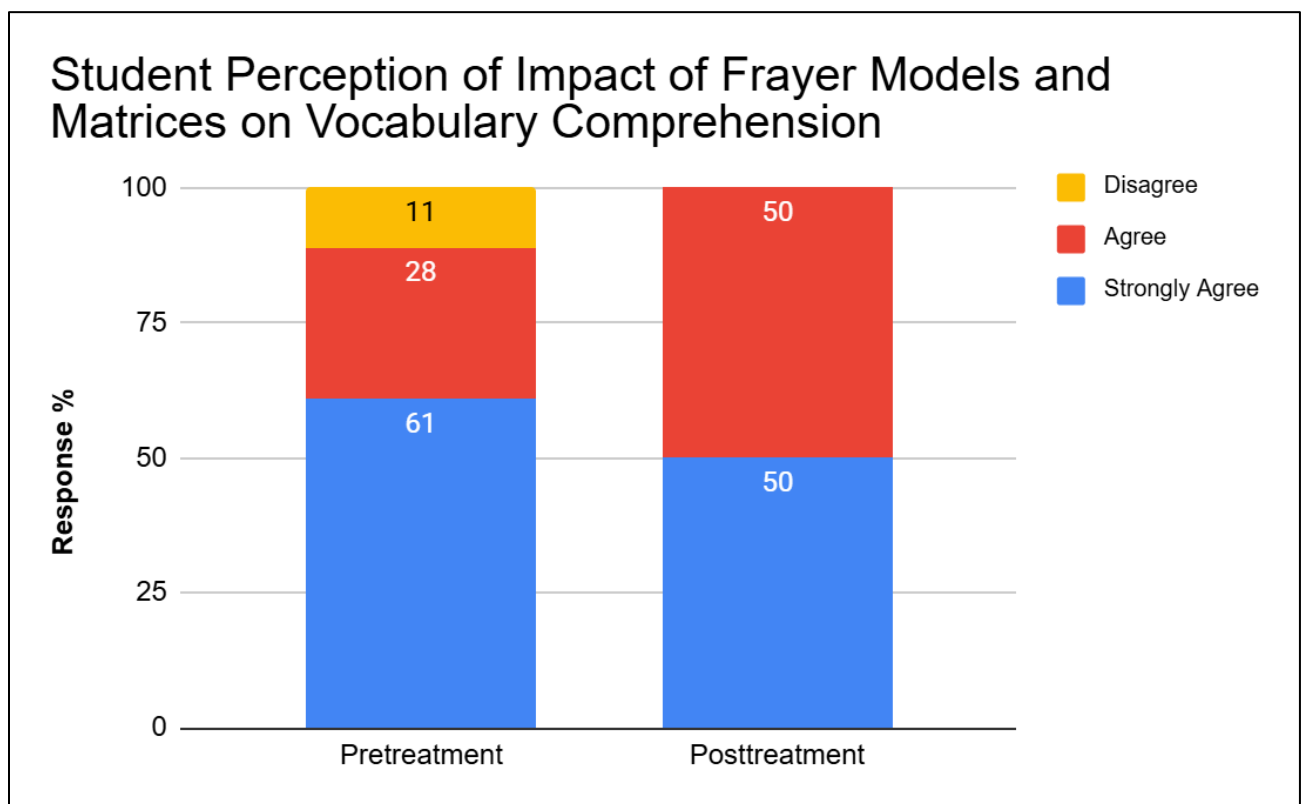


Figure 5. Student perception that Frayer models were more effective than a vocabulary matrix for learning vocabulary terms and connections between terms, pre and posttreatment, ($n=18$).

Fifteen students responded to survey questions regarding their perception of how the use of Frayer models affected comprehension of vocabulary terms and their quiz grade (Figure 6).

Five students either did not complete the response or responded with multiple answers.

Posttreatment responses (Mdn=4) were significantly higher than pretreatment responses (Mdn=3), $p = 0.028$, indicating an increase in students' perceptions of the usefulness of this strategy. Pretreatment survey responses indicated 80% strongly agreed/agreed, while posttreatment survey responses resulted in 93% strongly agreed/agreed in the posttreatment survey. After using Frayer models, 50% of posttreatment survey responses strongly agreed and 44% agreed they would like to use them again. One student disagreed with using Frayer models and added a comment that they did not need organizers to help with vocabulary in this unit.

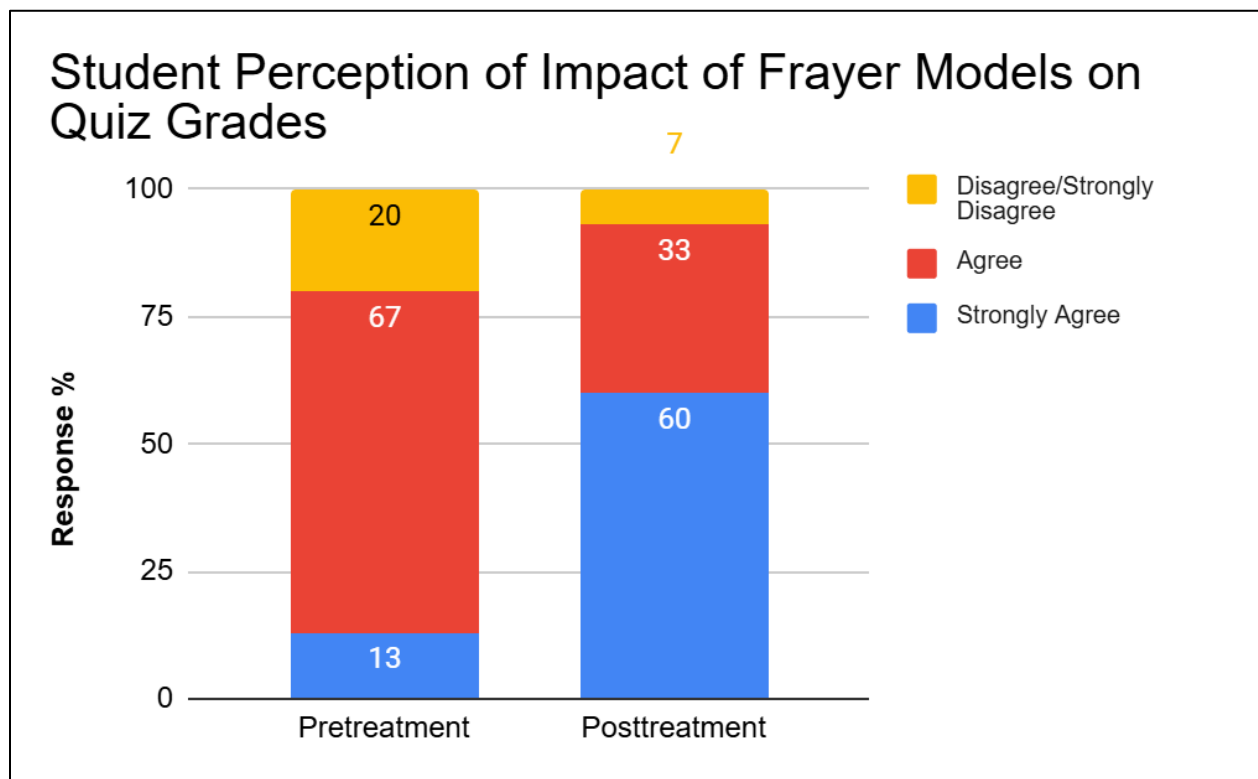


Figure 6. Student perceptions of Frayer models impacting quiz grades, pre and posttreatment, ($n=15$).

Interactive Word Walls

The elementary level word wall had a medium normalized gain of .601 while the interactive word wall had a high normalized gain of .748 between pre and posttreatment content-based quizzes. Twenty students submitted survey responses regarding use of interactive word walls as a vocabulary tool. The Wilcoxon Signed Rank test results show a significant difference between pretreatment response (Mdn = 2.5) and posttreatment response (Mdn = 3), $p=0.002$. Pretreatment responses indicated 50% of students strongly agreed/agreed which increased to 100% on the posttreatment survey (Figure 7).

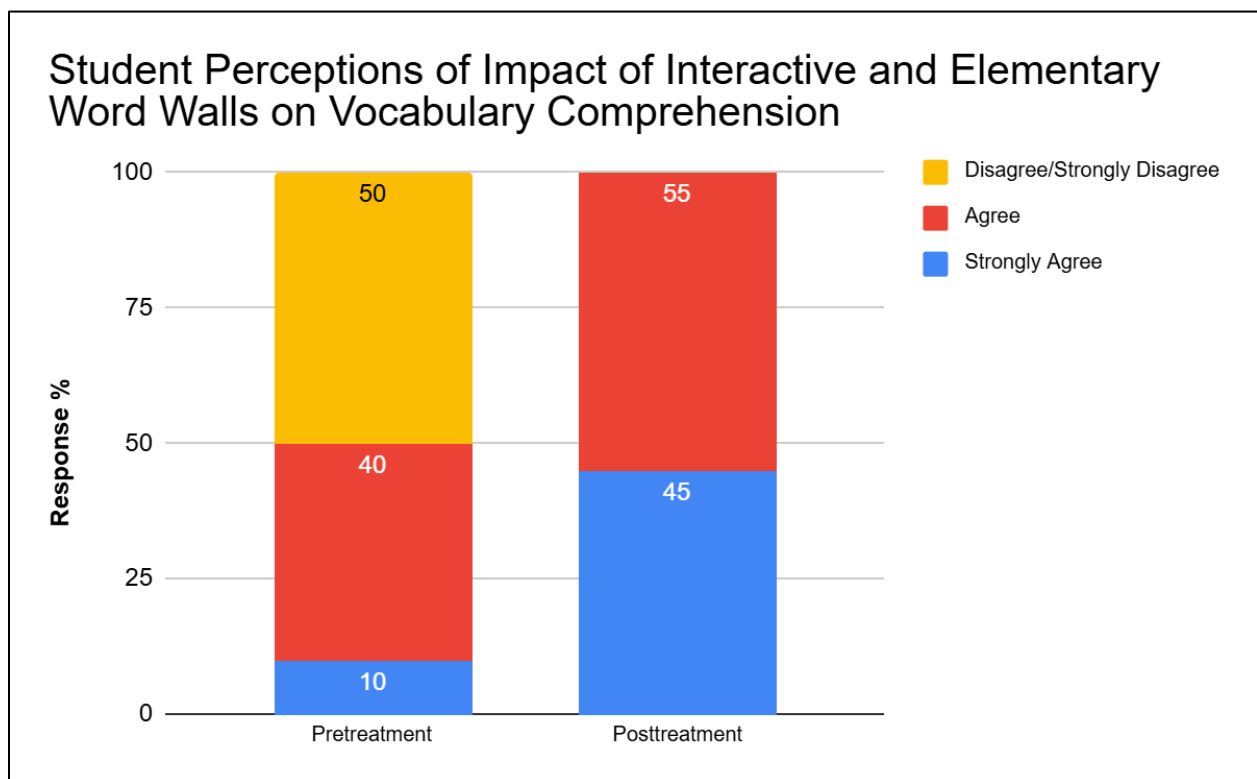


Figure 7. Student perceptions of using an interactive word wall to understand key terms and the connections between them, ($N=20$).

Student anticipation for being engaged and actual engagement while working in groups to create interactive word walls increased between pre and posttreatment responses with all students

agreeing that they would like to use interactive word walls again. Pretreatment responses included 60% agreement and 40% disagreement. After students created their interactive word wall, 100% strongly agreed/agreed that they had been engaged and would like to use interactive word walls again. Differences between the pretreatment response ($Mdn=2$), and posttreatment response ($Mdn=3$), $p = 0.001$, suggest a significant increase in student perceptions that use of the interactive word wall had a greater impact on their posttest grade than use of an elementary level word wall. Pretreatment responses showed 45% strongly agreeing/agreeing represented 45% with posttreatment responses increasing to 100% strongly agreeing/agreeing (Figure 8).

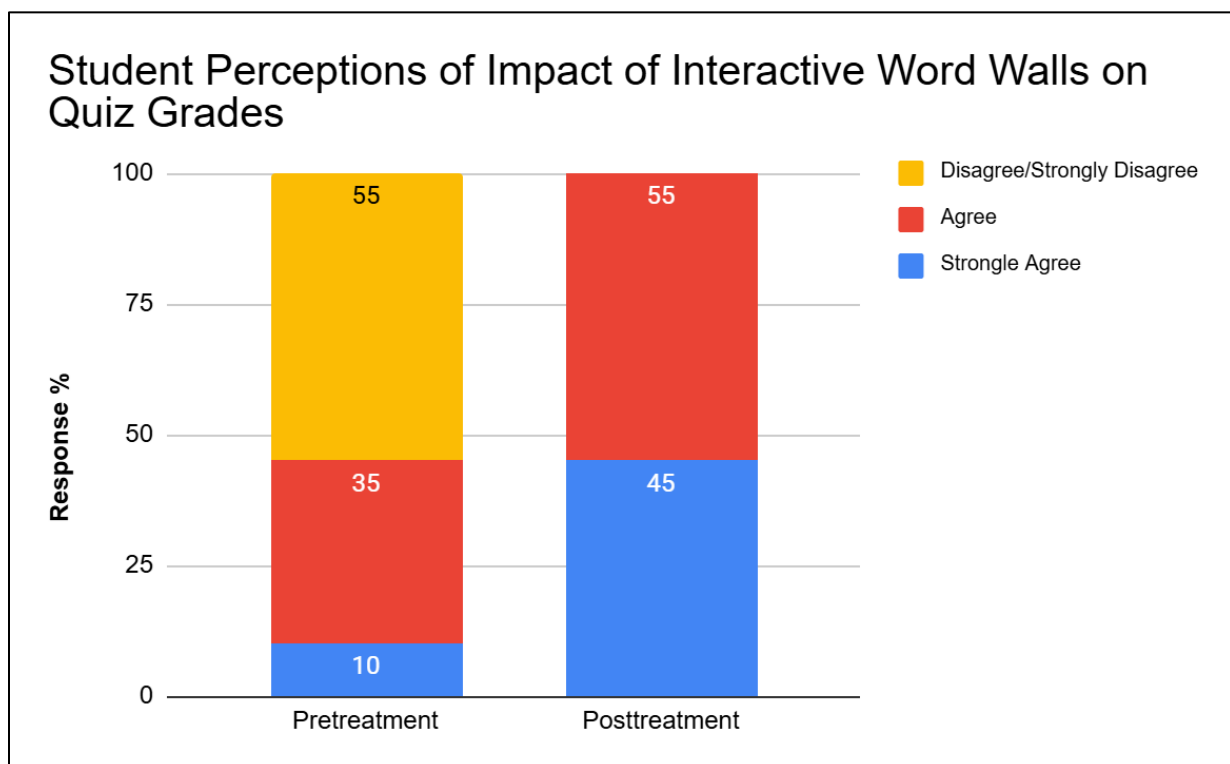


Figure 8. Use of an interactive word wall had a greater impact on student grades compared to an elementary level word wall, pre and post treatments, ($N=20$).

Game Use Results

The final data set assessed effectiveness of using paper and computer-based games as vocabulary strategies (Figure 9). The nontreatment unit was on balancing equations and the treatment unit was on chemical reactions. The nontreatment unit had a medium normalized gain of .669, while the treatment unit had a high normalized gain of .707 between pre and posttests. Students' perceptions on whether games helped them understand vocabulary in the treatment chemical reactions unit had a null significance, $\geq .05$, between pretreatment response (Mdn = 3) and posttreatment response (Mdn = 3), $p = 0.272$. Pretreatment survey responses indicated 85% strongly agreed/agreed that using games improved comprehension. These responses decreased to 80% on the posttreatment.

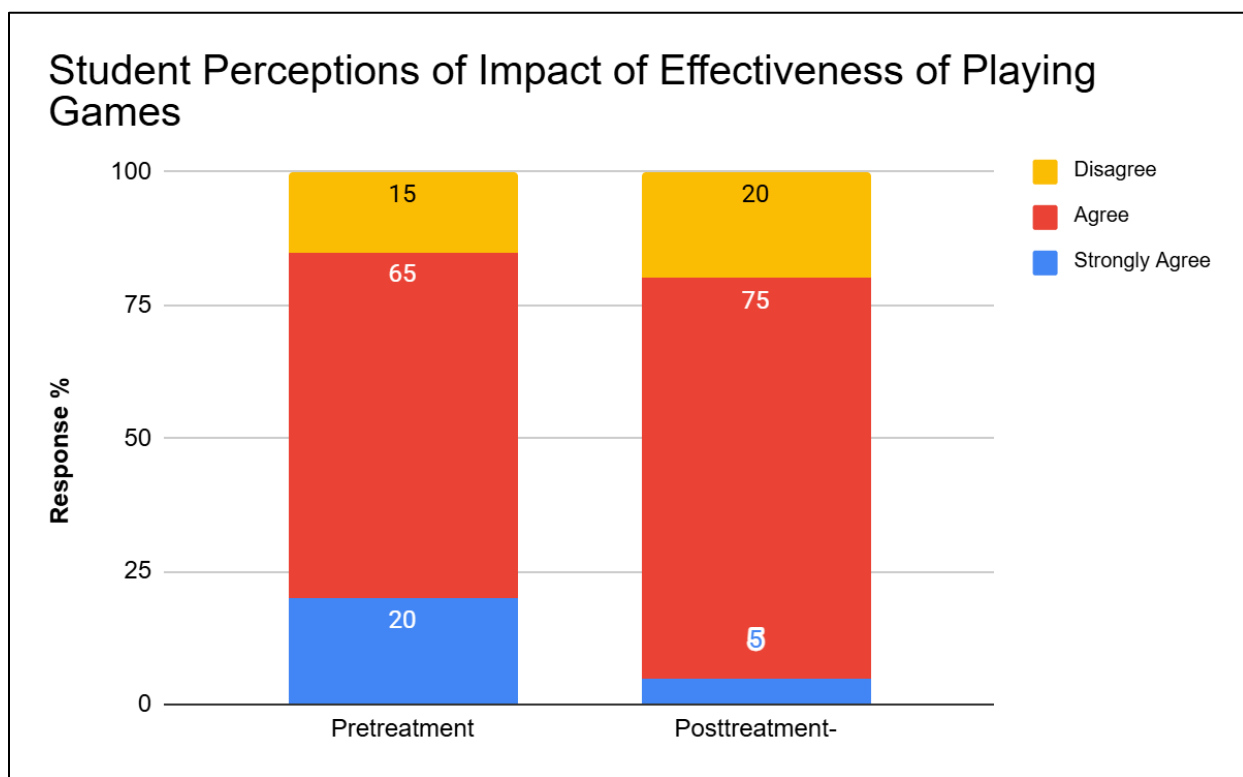


Figure 9. Students' perceptions of effectiveness of using paper and computer-based games, pre and posttreatment responses, ($N=20$).

Student perception that playing games impacted their grade had null significance between pretreatment response (Mdn = 3) and posttreatment response (Mdn = 3), $p = 0.155$. Pretreatment survey results indicated that 85% strongly agreed/agreed that playing games would impact their grade, and these responses decreased to 75% on the posttreatment survey (Figure 10).

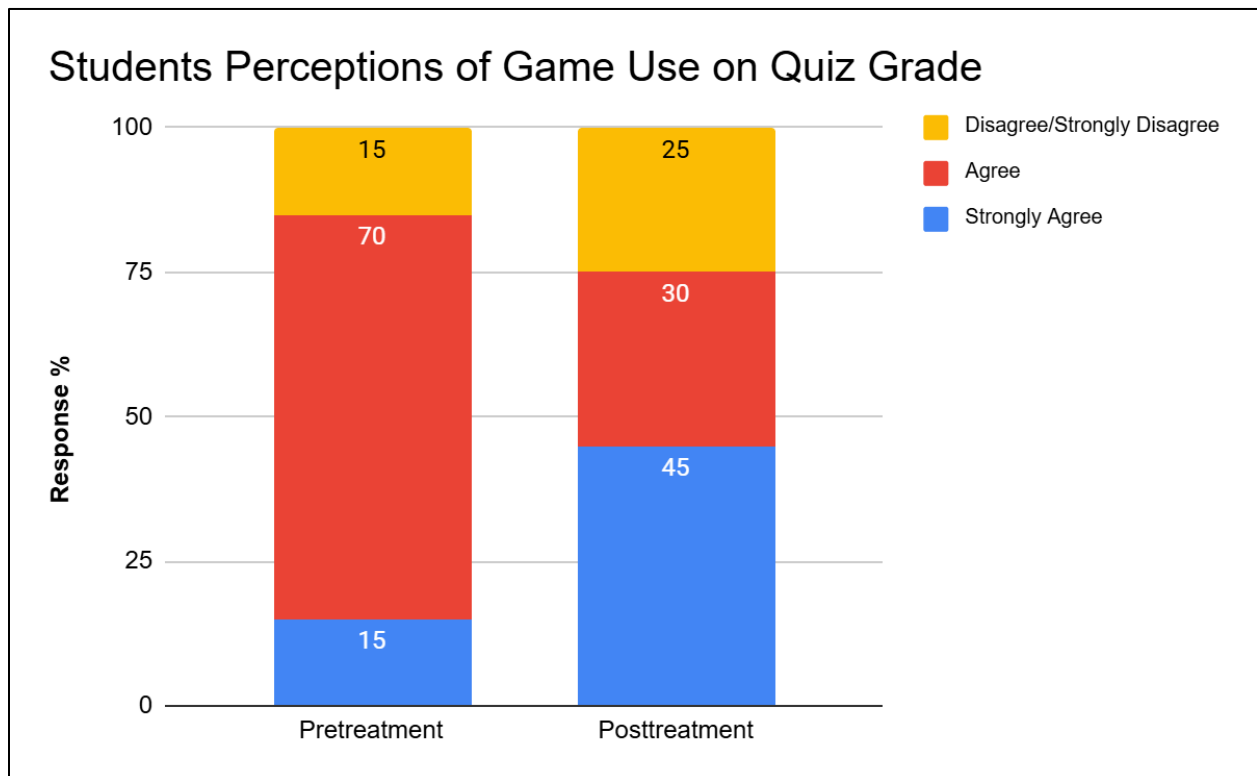


Figure 10. Survey responses for student perception of whether using games for review had an impact on their grade, pre and posttreatment, ($N=20$).

Pretreatment survey results showed that 50% of students preferred computer-based games, 30% preferred paper and 20% had no preference. Posttreatment responses dropped to 40%, preferring computer-based games. Student survey responses about potential and actual engagement while playing content-based games were differentiated as being paper-based or computer-based. Pretreatment survey responses indicated that 80% strongly agreed/agreed that they would be engaged while playing computer-based games which decreased to 7% on the

posttreatment survey. Teacher observations of student behavior noted that a few students had to be reminded to return to their designated work areas because they did not like their teacher assigned groups. This resulted in students needing additional reminders on how to follow directions to complete the paper-based escape room. Pretreatment responses indicated 85% of students had anticipated being engaged while playing computer-based games, which decreased to 70% on the posttreatment survey. During the computer-based game, students stated that they did not want to play the game because they had already played Blooket in another class.

Overall Comparison Between Strategies

Normalized gain comparison between pre and posttest scores indicated that the basic vocabulary matrix was the most effective strategy for student growth with a gain of .776. The interactive word wall and use of games also had high normalized gains with values of .748 and .707. Normalized gain values with a range between .669 to .517 reflected medium growth. Vocabulary strategies were not used for the balancing equations unit, which had a growth of .669 while the elementary word wall had a growth of .601 followed by the Frayer model with a growth of .517 (Figure 11).

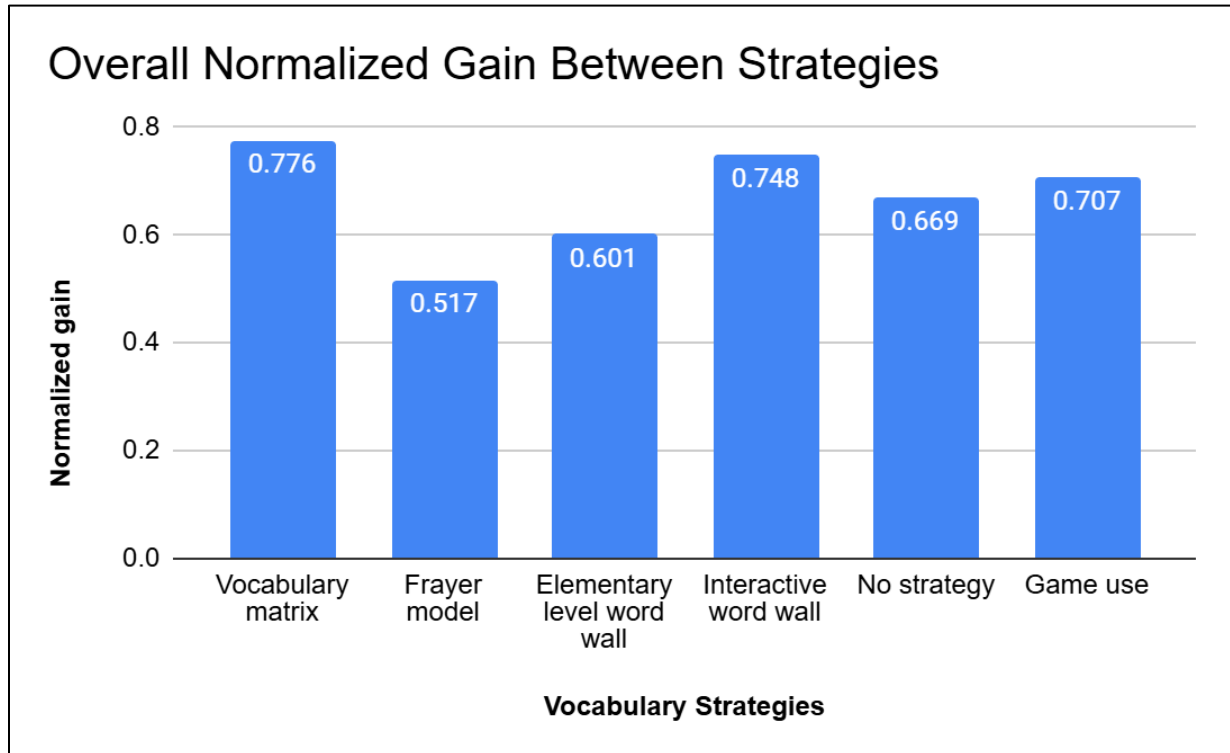


Figure 11. An overall comparison between normalized gain scores indicated that the basic vocabulary matrix was the most effective strategy based on student growth between pretest and posttest scores with a gain of .776.

Students responded that the Frayer model and interactive word wall helped them understand vocabulary terms and make connections. When the responses were 100% strongly agree/agree, the Frayer model had the most strongly agree responses, 50%, while the interactive word wall was very close with 45% strongly agreeing (Figure 12).

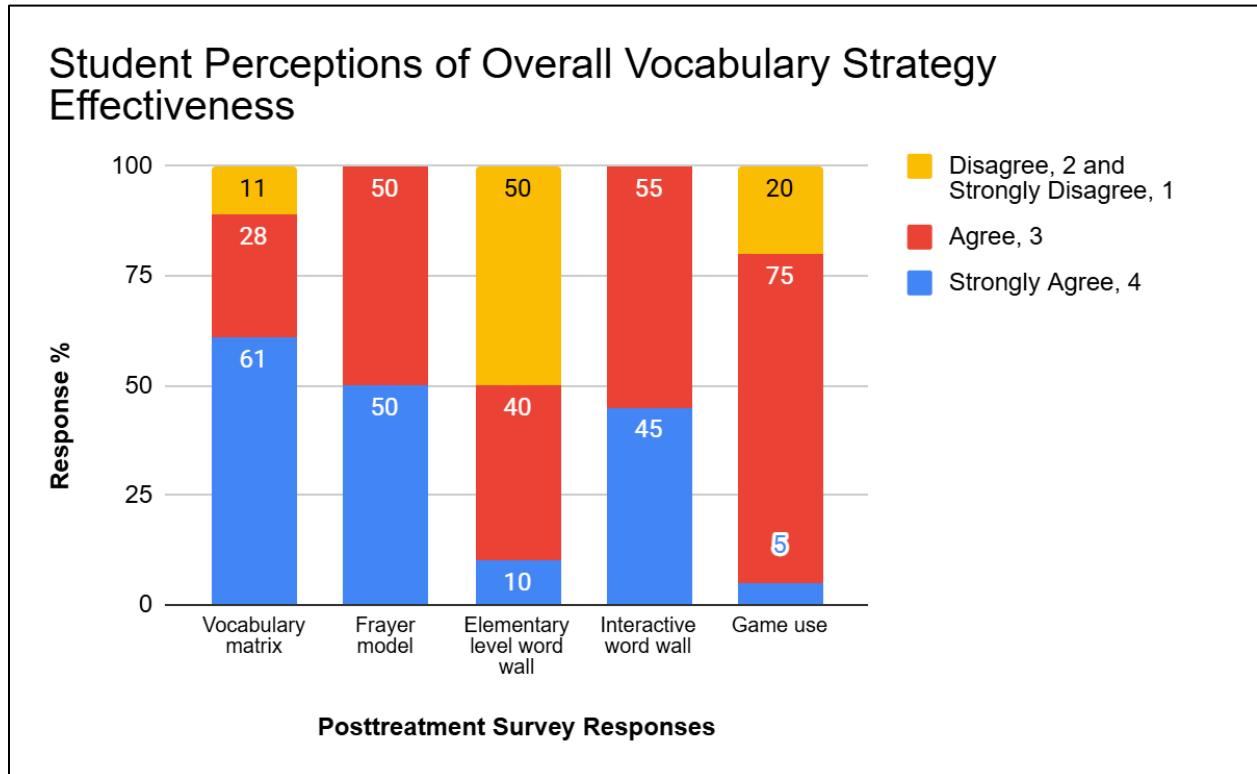


Figure 12. Survey responses indicated that all students perceived that the Frayer model and interactive word wall helped them understand vocabulary terms and make connections.

Student responses identifying which strategy they felt had the most impact on their grade were compared. Responses indicated that the Frayer model had the most impact on student grade with 93% strongly agree/agree. The interactive word wall had strongly agree/agree responses of 90% while the vocabulary matrix had 80% strongly agree/agree responses identified as impacting their grade. Student responses regarding game use were 75% strongly agree/agree it impacted their grade while 45% strongly agree/agree the elementary word wall impacted their grade (Figure 13).

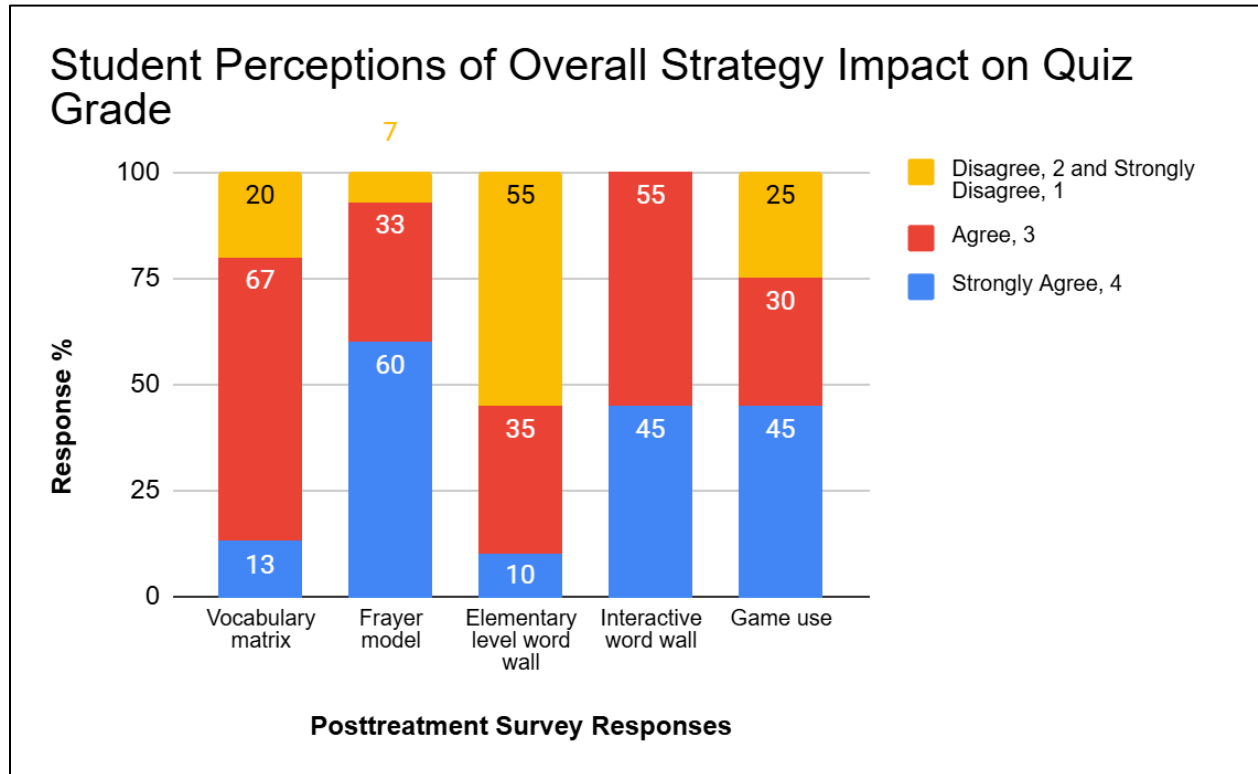


Figure 13. Student survey responses to the statement indicate that the Frayer model had the most impact on student grades.

CHAPTER FIVE

VALUE: REASONING AND REFLECTION

Claims from the Study

While vocabulary strategies did not consistently increase test scores, they significantly improved student engagement, confidence and perceived understanding. Normalized gain responses did not indicate that the use of vocabulary strategies had an impact on high school students' science content-based assessments. Student perception regarding strategy use disagreed by reflecting that vocabulary strategies had a positive impact on science content-based assessments. Likert scale survey responses indicated that all students strongly agreed or agreed that Frayer models, interactive word walls and using games helped them understand their vocabulary terms and make content-based connections between them. Over 90% of student responses indicated that use of Frayer models and interactive word walls had a positive impact on their grade.

Value of the Study and Consideration for Future Research

Normalized gain reflects the students' growth between pretest and posttest assessment scores based on academic content, but an additional variable is difficulty of content. The highest normalized gain, .776, reflected the vocabulary matrix that asked students to define and provide a picture for the terms. The content for this strategy was valence electrons, which required students to determine the number of valence electrons based on location in an atom and which group the element belongs to on the periodic table. Students were also required to draw Lewis dots and explain core shielding. Contrary to Buchanan (2015), who saw an increase in posttest

scores, my students' Frayer model posttests had the lowest normalized gain value, .517. Students had to convert elements to ions, including the correct charge and oxidation number. They also had to differentiate between covalent and ionic bonds and write correct chemical formulas following the HONC1234 rules.

My co-teacher, Colleen Skaggs, was surprised at the results because she had felt that use of the Frayer models had increased student engagement and should have had a positive impact on their grades. She added that students were correctly using terms in discourse while they worked through activities. When I asked another teacher, Teresa Fewlass, who teaches history at Kent County High School in Maryland, why she thought the nontreatment scores were higher than the treatment scores, she responded that students rely on their notes but do not take the time to interpret them.

Student responses on the Likert scale survey identified the Frayer model as the most beneficial vocabulary strategy with 50% of students strongly agreeing and 50% of students agreeing that it helped them learn content. Students also identified it as the strategy that they perceived to have the greatest impact on their grade at 93%. Skaggs stated that when she was first introduced to the Frayer model she didn't see the point in students needing to provide examples and nonexamples but as she worked with students, she saw the benefit in the clarification. As students worked through their assignments and reflected on the Frayer models they seemed to be more aware of what constituted a correct answer compared to what would be considered an incorrect answer. Skaggs also stated that she pulled fewer students into small groups for extra help and that it was easier to help small group students find correct responses in their notes with less effort from her.

In the future, I plan to use Frayer models to introduce vocabulary to students who require pre teaching of terms and as a review strategy midway through a lesson for students who do not require pre teaching of terms. Students will need to be taught how to use the Frayer model as a resource, practicing locating terms on it and applying the meaning of the terms to content not just looking at it for word for word answer options. Depending on the content, I may combine the Frayer model with the basic matrix for terminology that does not need specific clarification for what the term is or is not (Figure 14).

Volcano Vocab

Term	Definition	Image
Conical	triangle-shaped hill formed as material from volcanic eruptions piles up around the volcanic vent	
Lava tube	lava in the tube drains out, it will leave an empty cave. Lava tubes are common in low-viscosity volcanic systems.	https://www.youtube.com/shorts/qW49CnS8dZc?feature=share 
Vent	opening in the Earth's crust <ul style="list-style-type: none">This is not the same vent discussed in Mr. Shane's class	

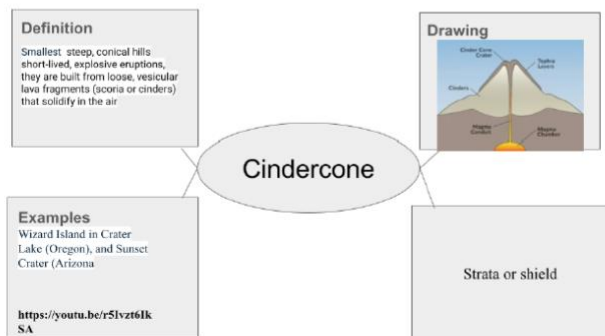


Figure 14. The portion of the organizer that describes parts of a volcano are in matrix format while the specific types of volcanoes are in Frayer model format.

I will not be using the elementary word wall again, only referencing terms by themselves in word banks on assessments. Students will continue to use interactive word walls; survey responses indicated that all students found the word wall helpful for learning terms and making connections between them while 90% of students strongly agreed or agreed that the interactive word wall impacted their assessment grade consistent with Jackson (2018). Skaggs stated that she was surprised at the level of engagement students displayed while assembling their interactive word walls. Students who normally do not participate were talking to other students about the content and helping move cards. One student stated that they were having fun. Skaggs also stated that she noticed students actively looking up at the interactive word wall posters during the posttest.

I will be very selective when utilizing game strategies for review although normalized gain resulted in a significant increase, similar to Hazar (2020), who stated that digital games that included animation and achievement goals resulted in students achieving higher test scores. My students' responses contradicted both Li (2020) and Zou (2020), who reported that students were more motivated to study and stay on task while playing games. Student responses indicated that they were bored because too many teachers had them play computer-based games, including Blookets and Kahoots. Student interest in paper-based games increased 5% on the posttreatment survey while their interest in computer-based games decreased by 10%. For units where it is challenging to provide hands-on activities, more paper-based games including escape rooms, and whodunnits will be utilized and my Blooket content will be converted into interactive word walls.

Mertler (2025) describes action research as being reflective and cyclical. With each investigation, new information is found, and more questions are raised. My future research efforts will compare pretreatment and posttreatment normalized gains from students selected because of low achievement due to learning disabilities, including low reading comprehension or behavior. I would also like to survey the same students in following years to determine if they continue to utilize any of these strategies. When I reflect on my methodology, I used teacher observations as a data collection tool for game use only. In the future, I will use personal teacher observations for all vocabulary strategies. After analyzing my co-teacher's observations, I realized that we do not always see the same things and students sometimes only comment to one of us.

Impact of Action Research on the Author

The challenges of working through this investigation have made me more aware of my students' academic and emotional needs. At the beginning of the investigation, I recognized that many of my students had low proficiency scores for comprehension. As we worked through strategies, I became aware of why they had low scores. I observed them becoming distracted or minimizing effort when they felt the task was too difficult, providing non-content related definitions to terms. They also struggled to make connections between content included in the notes that were provided for reference. To help my students focus, I started to provide visual clues; highlighting words and arrows pointing back to other areas of content, to help them select the best response. Some clues were more creative to keep their attention, such as showing them an image of my cat playing with laminated atoms; the cat has paws which are similar in sound to cations having positive charges (Figure 15).



Figure 15. The cat has paws, a word that has a sound similar to the term positive. Cations, or in this example, cat ions, have positive, or paws itive, charges.

Students learned that it was okay if they made a mistake while sharing answers because they were never the only one who made a mistake. I learned to be considerate with how I redirected students. When we reviewed answers, I was very careful to comment “yes, your answer is a possibility but is it the best answer?” Using vocabulary strategies that students valued improved their attitudes toward completing activities and they started to ask if we would be using certain strategies. During the chemical reactions unit, where the strategy utilized was games, students asked if we could use the Frayer model. The use of strategies increased my students’ confidence levels. My classroom is the only 9th-grade science class surrounded by epidemiology, physics and honors math. Other teachers and their students have made jokes about being able to identify my students when they walk down the hall. After I posted the interactive

word wall posters in the hallway, the other students and teachers took time to look at the assignments and started conversations with my students about the connections they illustrated.

At the end of this investigation, I have become more considerate of my students' academic needs, their feelings about their academic abilities and how these feelings affect them when they are around other students who are not in team approach to mastery (TAM) classes. I have found ways to utilize methods that encourage my students to value the strategies that are designed to help them so they can ask for the tools they need to succeed. My students see me as a caring teacher who wants them to enjoy learning and to be successful. My colleagues see me as the teacher who has found a way to challenge the students who are a challenge.

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APPENDICES

APPENDIX A: IRB APPROVAL

IRB INFORMED CONSENT FORM

My Protocols

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11/19/2025 4:28 PM

Protocol #	Reference #	Version #	Association	Principal Investigator	Protocol Type	Title	Submission Date	Viable Date	Modified Date	Expiration Date	Renewal Date	Approval Date	Status Date	Assigned Review Type	Protocol Status	Product Family	Parent Protocol #
2025-2382-EXEMPT	2382	1	PI, Author, Creator	Fewlass, Kara	Original	The Effects of Using Vocabulary Strategies with High School Students on Science Content-based Assessments	11/17/2025		11/19/2025	11/19/2030	11/19/2030	11/19/2025	11/19/2025	Exemption	Approved	Human Studies	

Figure 16. The IRB approved consent form completed November 19, 2025.

APPENDIX B: VALENCE ELECTRON AND LEWIS DOT
PRODUCT

Valence Electron and Lewis Dot Product Valence

Valence Electron and Lewis Dot Product

- Periodic Table is on the last page

1. Valence electrons _____ (1pt)

- A. are the only charge of an atom
- B. bond with electrons in the outer orbitals of other atoms
- C. help us identify mass of an atom
- D. all the above

2. Valence electrons are found in the _____. (1 pt)

- A. Outer orbital
- B. Inner orbital
- C. Nucleus
- D. S levels

3. The number of valence electrons is the same as the _____ number on the periodic table. (2 pts)

- A. Group
- B. Period
- C. Protons
- D. Atomic number

4. Argon is a noble gas. How many valence electrons does it have? (2 pts)
refer to periodic table)

- A. 39.9
- B. 8
- C. 18
- D. 40

5. The Lewis Dot structure for Nitrogen has _____ dots. (3 pts)
(refer to periodic table)

6. Draw the Lewis Dot structure for Mg. (3 pts)

7. Core shielding is defined as “ability to shield or block the valence shell from attraction to the nucleus.” (5 pts)

Describe how one of the pictures below illustrates this theory.

Include answers to 1,2& 3

1. A statement identifying the nucleus. (1 pt)
2. A statement identifying core electrons and their behavior. (2 pts)
- A statement identifying valence electrons and their behavior. (2 pts)



Figure 17. Core shielding analogies compare to an elephant family and football players.

8. Explain the relationship between Lewis dots, valence electrons and the periodic table. Provide an example for Carbon. (4 pts)

PERIODIC TABLE

1 H Hydrogen 1.008																	10 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948										
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 84.798

Figure 18. A segment of the periodic table provided for student reference.

Grades

A= 19-21 B= 15-18 C= 10-14 D= 6-9 F= 0-5

APPENDIX C: VALENCE ELECTRON AND LEWIS DOT
VOCABULARY MATRIX

Valence Electrons and Lewis Dots Vocabulary Matrix

Obj: Improve word recognition skills within the context of this unit

Complete the definition for each term. Please use words you understand, reference your notes, and do not copy directly from an online search. Draw your images clearly so they can help you visualize what the terms mean.

Table 2. A basic matrix asking students for definitions and images.

Term	Definition	Image
Group		
Period		
Core electron		
Valence electron		
Core shielding		
Lewis dot		

APPENDIX D: BONDING PRODUCT: COVALENT AND
IONIC

Bonding Product: Covalent and Ionic

1. A _____ bond occurs when 2 nonmetals share electrons. 1 pt
- A. Ionic
 - B. Covalent
 - C. Metallic
 - D. Hydrogen
2. The type of covalent bond that occurs when pairs of electrons are shared between the same 2 atoms is a _____ bond. 1 pt
- A. Single
 - B. Double
 - C. Triple
3. When interpreting the HONC1234 rule, the numbers represent _____ and _____. 2 pts
- A. Electrons needed to fill the atom's valence shell
 - B. Number of bonds needed to stabilize the element
 - C. Lewis dots
 - D. The atom's charge
4. What is the chemical formula for the final product of Mg and Cl? 2 pts
- A. MgCl_2
 - B. MgCl
 - C. Mg_2Cl
 - D. MgCl_3

5. Explain what the symbol K^+ means.

Include: oxidation number and number of electrons transferred

3 pts

6. Explain the transfer of electrons in an ionic bond. Include how

charge is impacted.

3 pts

7. Identify which type of bond, covalent or ionic, occurs

when Al and O form a compound. Write the chemical formula

and explain your reasons.

4 pts

8. Glucose is a simple sugar that your body uses for energy

4 pts

and storing fat. There are 2 molecular structures below.

Circle the incorrect structure and explain why it is incorrect

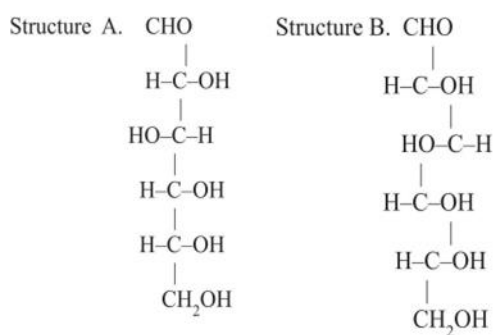


Figure 19. Students select the incorrect isomer and explain why it is incorrect.

GRADES:

A= 18 - 20

B= 15 - 17

C= 11-14

D= 6-10

F = 0-5

APPENDIX E: PRE BONDING FRAYER MODEL LIKERT
SCALE SURVEY

Pre Bonding Frayer Model Likert Scale

1. I think using the new Frayer model will help me understand vocabulary in this unit.

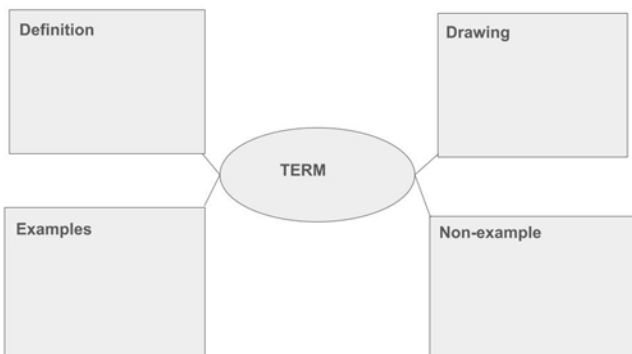


Figure 20. A blank Frayer model.

Circle the best answer:

Strongly Agree

Agree

Disagree

Strongly Disagree

2. I think that using the Frayer model will help me understand the meaning of the terms better than organizers that only asked me to define the term and draw a picture Circle the best answer:

Strongly Agree

Agree

Disagree

Strongly Disagree

Term	Definition	Image
Valence electron	Electrons in the outer orbital that allow atoms to bond	
Lewis dot	Dots around the symbol so you don't have to draw a bohr model. Each dot = a valence electron	
Core electron	Electrons on inner orbitals	

Figure 21. A visual reminder of what the students' vocabulary matrix should look like.

Circle the best answer:

Strongly Agree

Agree

Disagree

Strongly Disagree

3. I think that using a Frayer Model will help me better comprehend vocabulary terms on my quiz and improve my grade.

Circle the best answer:

Strongly Agree

Agree

Disagree

Strongly Disagree

APPENDIX F: BONDING FRAYER MODEL

Bonding Frayer Model

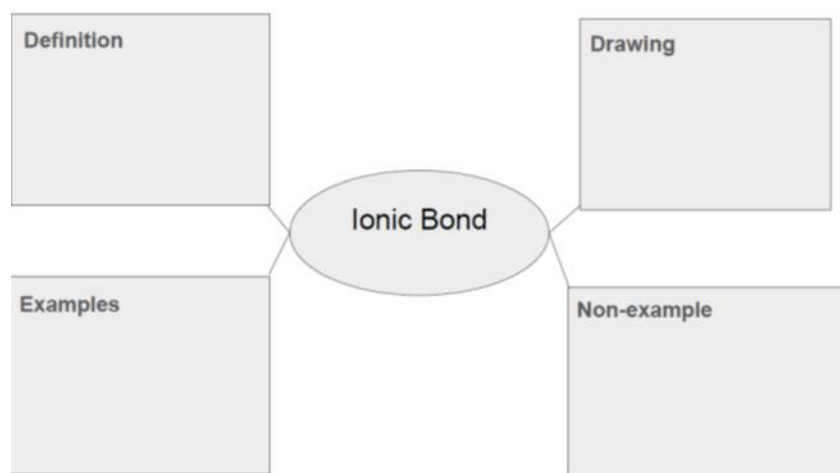


Figure 22. A blank ionic bond Frayer model.

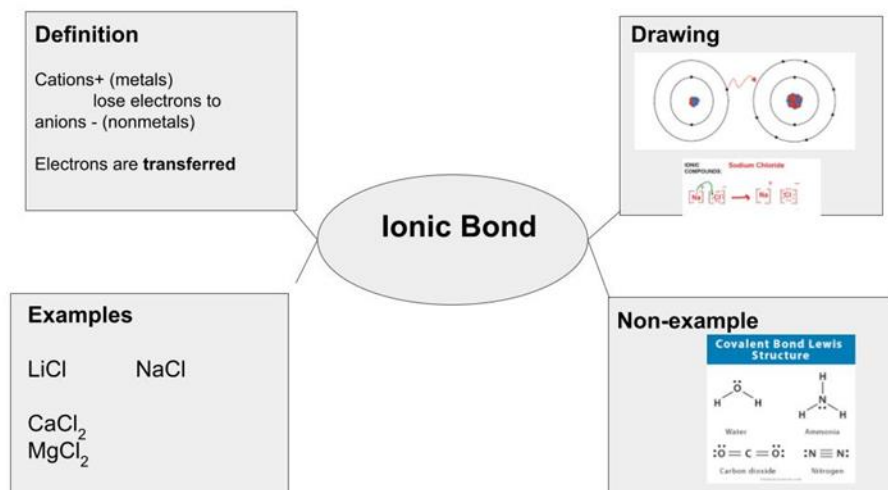


Figure 23. A completed ionic bond Frayer model.

APPENDIX G: POST BONDING FRAYER MODEL LIKERT
SCALE SURVEY

Post Bonding Frayer Model Likert Scale Survey

1. I think the new Frayer model that we used in class helped me understand the vocabulary in this unit.

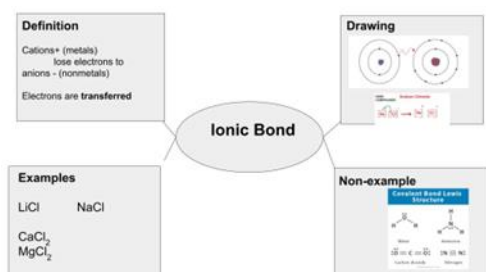


Figure 24. A completed Frayer model for visual reference.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

2. I think the Frayer model helped me understand the meaning of the terms better than organizers that only asked to me define the term and draw a picture.

Term	Definition	Image
Valence electron	Electrons in the outer orbital that allow atoms to bond	
Lewis dot	Dots around the symbol so you don't have to draw a bohr model. Each dot = a valence electron	
Core electron	Electrons on inner orbitals	

Figure 25. A complete matrix for visual reference.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

3. The Frayer Model helped me better comprehend vocabulary terms on my quiz, impacting my grade.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

4. I would use Frayer models again to help me comprehend my vocabulary terms.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

APPENDIX H: CO-TEACHER OBSERVATION FORM

Co-Teacher Observation Form

For each area of focus please identify how often each behavior is occurring using the rating scale.

3 - uses strategies and correct terminology independently

2 - needs a few reminders to reference strategies and use correct terminology

1 - needs multiple reminders to reference strategies and use correct terminology

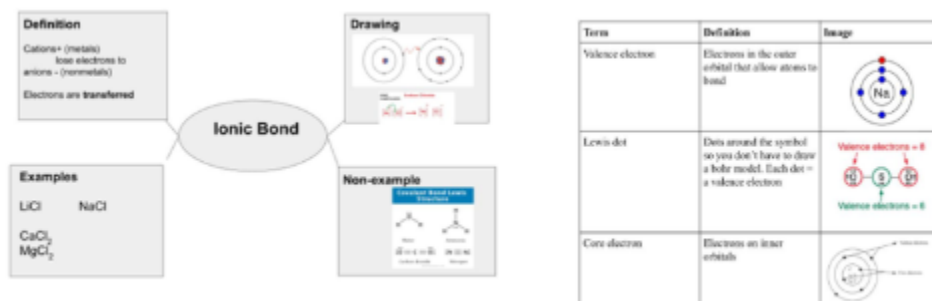
0 - does not reference strategies or use correct terminology

Table 3. A data collection tool for monitoring vocabulary use in writing and discourse.

Student	References strategy paper or poster.	Uses terminology correctly in conversation and while asking questions	Uses terminology correctly in writing	Additional Comments
1				
2				
3				
4				
5				
6				

APPENDIX I: CO-TEACHER BONDING FRAYER MODEL
INTERVIEW

Co-teacher Interview Bonding Frayer Model Interview



Figures 26. A Frayer model and matrix are shown as comparison.

1. Do you think the Frayer model helped students stay engaged with vocabulary in this unit?

Strongly Agree

Agree

Disagree

Strongly Disagree

Comments:

2. Do you think the Frayer model helped students understand the meaning of the terms better than organizers that only asked you to define the term and draw a picture?

Strongly Agree

Agree

Disagree

Strongly Disagree

Comments:

3. Do you feel that use of the Frayer Model helped students to better comprehend vocabulary terms on the quiz and had a positive impact on their grade?

Strongly Agree

Agree

Disagree

Strongly Disagree

Comments:

4. Do you feel students should continue to use Frayer models instead of the regular definition/drawing organizers?

Strongly Agree

Agree

Disagree

Strongly Disagree

Comments:

--

APPENDIX J: PERIODIC TRENDS PRODUCT

Periodic Trends Product

*Reference the atomic radius and effective nuclear charge charts on the last page

1. The _____ increases as you look down a vertical group on the periodic table. 1pt
A. number of valence electrons
B. metallic properties
C. atomic size
D. number of bonds
2. Metallic properties _____ as you move from left to right across the periods. 1pt
A. stay the same
B. decrease
C. increase
D. alternate increase and decrease
3. What do all the elements in Group 2 have in common? 2pts
A. number of orbitals
B. number of valence electrons
C. full orbitals
D. number of core electrons
4. The most reactive elements on the periodic table are located _____ and _____. 2pts
A. top left, top right
B. bottom left, top right
C. top right, bottom right
D. bottom right, top left
5. Which series of elements demonstrates increasing atomic radius? 3pts
A. F, N, Al, P
B. O, Si, Ca, Rb
C. K, Al, N, O
D. H, B, He, N

6. Which series of elements demonstrates increasing effective nuclear charge?

3pts

- A. Li, B, N, F
- B. B, Al, Mg, P, Na
- C. H, Li, He, Na
- D. Ar, Cl, Al, Li

7. Explain why atomic radius increases as Group numbers decrease and Period numbers increase.

4pts

8. Explain the concept of effective nuclear charge using the graph.

4pts

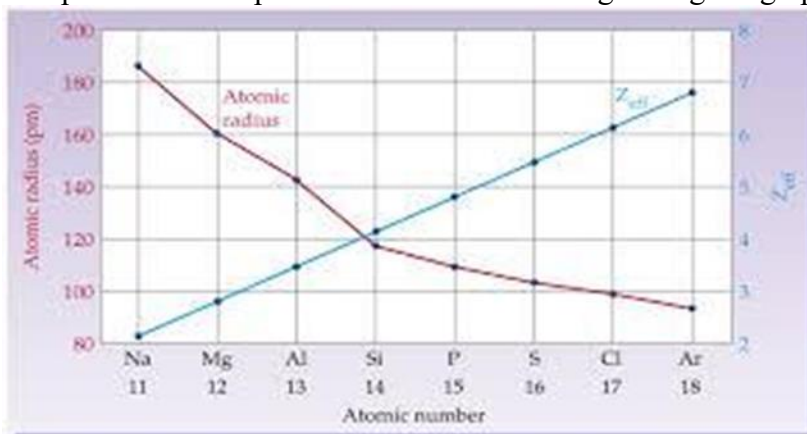


Figure 27. A graph showing the intercept of atomic radius and number increase.

ATOMIC RADIUS

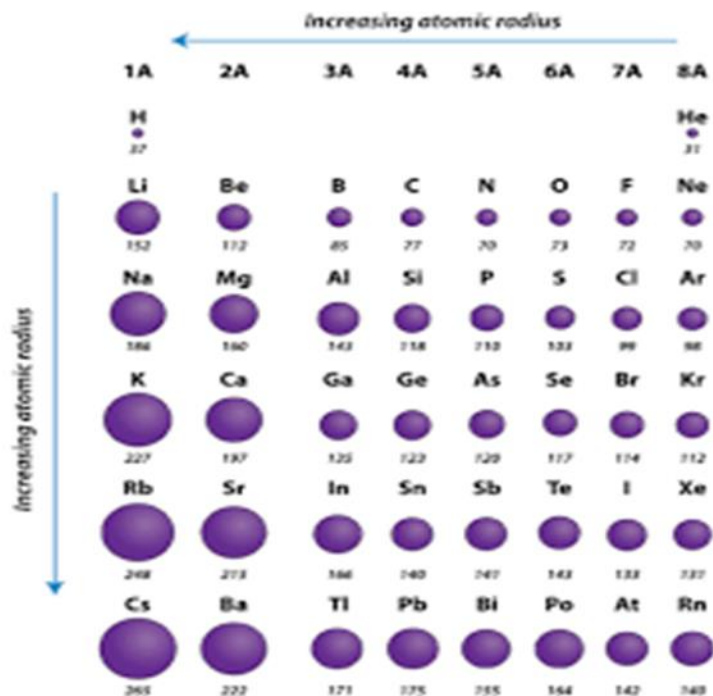


Figure 28. Atomic radius decreases as you go left to right across periods.

EFFECTIVE NUCLEAR CHARGE

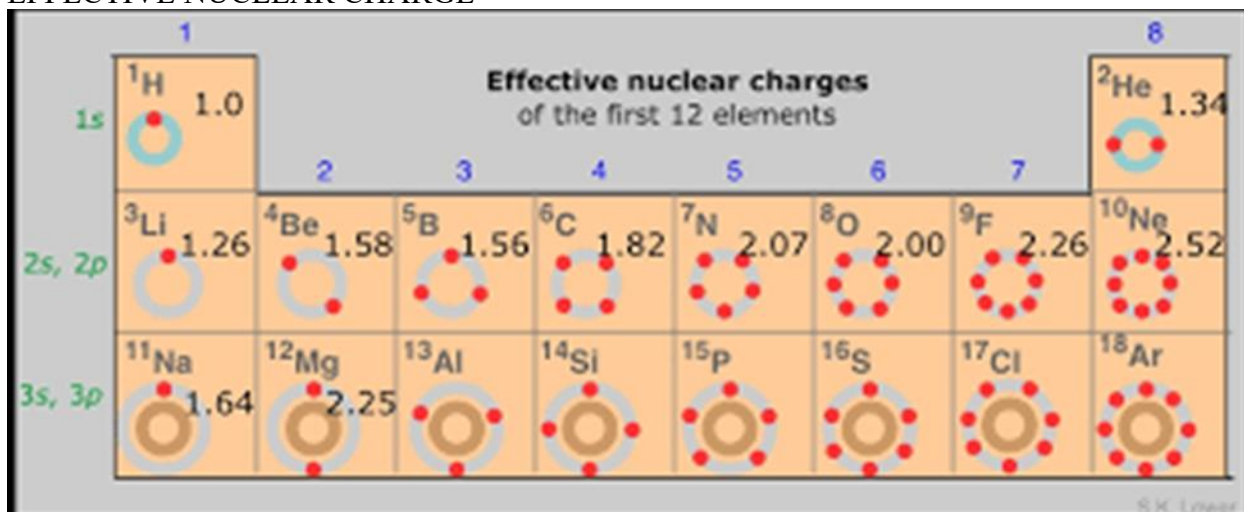


Figure 29. Effective nuclear charge increases as you go left to right across the periods.

GRADES: A= 18 - 20 B= 15 - 17 C= 11-14 D= 6-10 F = 0-5

APPENDIX K: ELECTRONEGATIVITY PRODUCT

Electronegativity Product

Both the Allen Scale and Polarity Scale are on the last page.

1. Which element has the greatest electronegativity?

1 pt

- A. C
- B. Be
- C. F
- D. O

2. Which element has the least electronegativity?

1 pt

- A. I
- B. Na
- C. C
- D. Al

3. Which group of elements demonstrates the trend of increasing electronegativity?

2 pts

- A. Li, Na, Mg
- B. Na, B, N
- C. Si, Al, O
- D. Mg, Be, Li

4. Which statement best describes electronegativity in the water molecule

2 pts

- A. Hydrogen has greater electronegativity than Oxygen
- B. Oxygen has greater electronegativity than Hydrogen
- C. The dipoles are pulling Oxygen to Hydrogen
- D. There are 2 Hydrogens and 1 Oxygen

DIPOLE MOMENTS



Figure 30. The dipole bond for water showing Oxygen has more energy.

5. Beryllium has an electronegativity value of 1.57. Florine has a value of 3.98. What type of bond is formed?

3 pts

- A. Ionic
- B. Polar covalent
- C. Nonpolar covalent
- D. Metallic

6. What type of bond occurs between Carbon and Nitrogen?

3 pts

- A. Ionic
- B. Polar covalent
- C. Nonpolar covalent
- D. Metallic

7. Explain why O₂ is a nonpolar bond.

4 pts

8. Identify the type of bond illustrated in the image. Explain how the image illustrates that type of bond.

4 pts

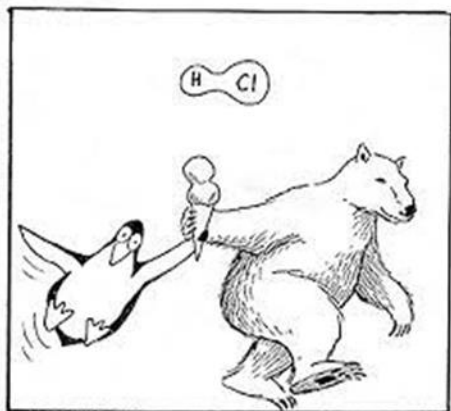


Figure 31. The polar bear is pulling the penguin.

ALLEN SCALE

H						
2.1						
Li	Be	B	C	N	O	F
1.0	1.5	2.0	2.5	3.0	3.5	4.0
Na	Mg	Al	Si	P	S	Cl
0.9	1.2	1.5	1.8	2.1	2.5	3.0
						Br
						2.8
						I
						2.5

Figure 32. The Allen scale.

POLARITY SCALE

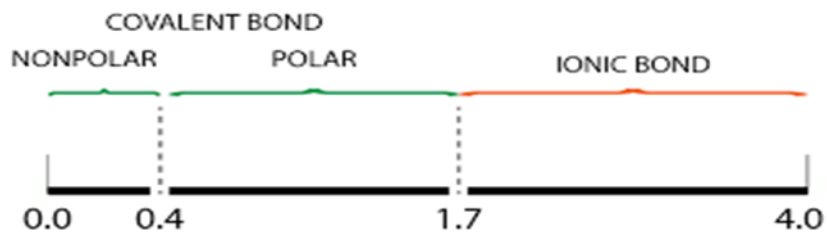


Figure 33. The polarity scale.

Grades:

A= 18 - 20

B= 15 - 17

C= 11 - 14

D= 6 - 10

F=0 – 5

APPENDIX L: PRE ELECTRONEGATIVITY INTERACTIVE
WORD WALL LIKERT SCALE SURVEY

Pre Electronegativity Interactive Word Wall Likert Scale Survey

1. I think that creating an interactive word wall will help me understand vocabulary in this unit.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

2. I will be engaged while creating an interactive word wall.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

3. I think that creating an interactive word wall will help me understand the meaning of the terms and the connections between them better than a traditional word wall.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

4. I feel that creating and referencing the interactive word wall will help me better comprehend vocabulary terms on my quiz and have a positive impact on my grade.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

APPENDIX M: POST ELECTRONEGATIVITY INTERACTIVE
WORD WALL LIKERT SCALE SURVEY

Post Electronegativity Interactive Word Wall Likert Scale Survey

1. I think that creating the interactive word wall helped me understand vocabulary in this unit.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

2. I was engaged while creating the interactive word wall.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

3. I think that creating the interactive word wall helped me understand the meaning of the terms and the connections between them better than the traditional word wall.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

4. I feel that creating and referencing the interactive word wall helped me better comprehend vocabulary terms on my quiz and had a positive impact on my grade.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

5. I would like to use interactive word walls again.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

APPENDIX N: CO-TEACHER ELECTRONEGATIVITY
INTERACTIVE WORD WALL INTERVIEW

Co-teacher Electronegativity Interactive Word Wall Interview

1. Do you think that creating the interactive word wall helped students understand vocabulary in this unit?

Strongly Agree

Agree

Disagree

Strongly Disagree

Comments:

--

2. Were students engaged while creating the interactive word wall?

Strongly Agree

Agree

Disagree

Strongly Disagree

Comments:

--

3. Do you think that creating the interactive word wall helped students better understand the meaning of the terms and the connections between them than the traditional word wall?

Strongly Agree

Agree

Disagree

Strongly Disagree

Comments:

--

4. Do you feel that creating and referencing the interactive word wall helped students better comprehend vocabulary terms on their quiz and had a positive impact on their grade?

Strongly Agree

Agree

Disagree

Strongly Disagree

Comments:

--

5. Would you like to use interactive word walls again?

Strongly Agree Agree Disagree Strongly Disagree

Comments:

--

APPENDIX O: BALANCING EQUATIONS PRODUCT

Balancing Equations Product

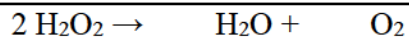
1. $\underline{\hspace{1cm}} \text{Ca}_3\text{N}_2 \rightarrow \underline{3} \text{Ca} + \underline{1} \text{N}_2$ 1 pt

2. $\underline{1} \text{O}_2 + \underline{2} \text{Cl}_2 \rightarrow \underline{\hspace{1cm}} \text{Cl}_2\text{O}$ 1 pt

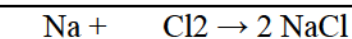
3. $\underline{\hspace{1cm}} \text{NaOH} + \text{FeCl}_2 \rightarrow \underline{\hspace{1cm}} \text{NaCl} + \text{Fe}(\text{OH})_2$ 2 pts

4. $\text{C}_3\text{H}_8 + \underline{\hspace{1cm}} \text{O}_2 \rightarrow \underline{3} \text{CO}_2 + \underline{\hspace{1cm}} \text{H}_2\text{O} + \text{heat}$ 2 pts

5. How many molecules of water and oxygen are produced when two molecules of hydrogen peroxide decompose? $\underline{\hspace{2cm}}$ molecules 3 pts



6. How many sodium atoms are required to produce two molecules of sodium chloride? $\underline{\hspace{2cm}}$ sodium atoms 3 pts



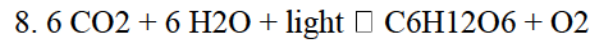
For #7 and #8, you have 3 things to do for each equation

A. is the equation balanced?

B. explain your answer

C. make corrections if the equation needs to be balanced

7. $\text{Cl}_2 + 2 \text{NaBr} \rightarrow 4 \text{NaCl} + 2 \text{Br}$ 4 pts



4 pts

GRADES:

A= 18 - 20

B= 15 - 17

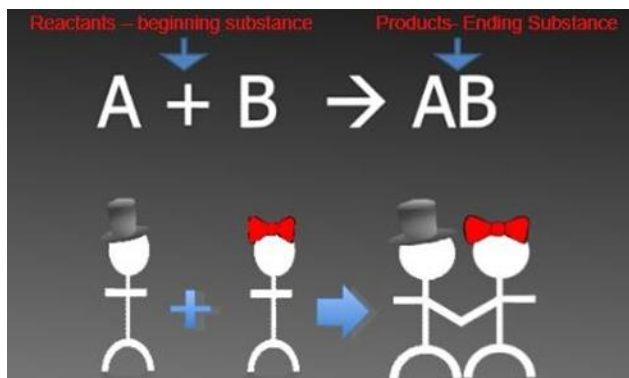
C= 11-14

D= 6-10

F = 0-5

APPENDIX P: CHEMICAL REACTIONS PRODUCT

Chemical Reactions Product



1 pt

Figure 34. Stick figures represent the relationship between compounds in a chemical reaction.

1. The type of reaction is

- A. Combustion
- B. Double Replacement
- C. Synthesis
- D. Single Replacement

2. The type of reaction is

1 pt

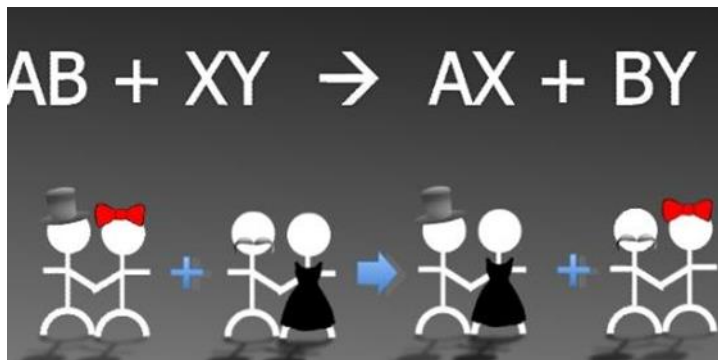
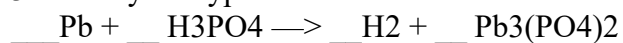


Figure 35. Stick figures represent the exchange of elements on both sides of the equation.

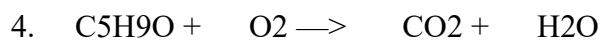
- A. Synthesis
- B. Single Replacement
- C. Double Replacement
- D. Combustion

3. Identify the type of reaction

2 pts



- A. Single Replacement
- B. Double Replacement
- C. Combustion
- D. Synthesis



2 pts

- A. Double Replacement
- B. Synthesis
- C. Combustion
- D. Single Replacement

Table 4. Data set for 5.6.7

Type of Reaction	Reactants	Products	Equation
Synthesis	Magnesium (Mg), Oxygen (O ₂)	Magnesium oxide (MgO)	$\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$
Decomposition	Mercury (II) oxide (HgO)	Mercury (Hg), Oxygen (O ₂)	$2\text{HgO} \rightarrow 2\text{Hg} + \text{O}_2$
Double Replacement	Copper (II) chloride (CuCl ₂), Hydrogen sulfide (H ₂ S)	Copper (II) sulfide (CuS), Hydrochloric acid (HCl)	$\text{CuCl}_2 + \text{H}_2\text{S} \rightarrow \text{CuS} + 2\text{HCl}$

5. Identify the type of reaction that occurs when magnesium reacts with oxygen to form magnesium oxide. Explain why magnesium oxide is that type of reaction.

3 pts

6. Identify the type of reaction that occurs when copper (II) chloride and hydrogen sulfide mix. Determine the expected products.

3 pts

7. Describe the process that occurs during the decomposition of mercury (II) oxide. Include the products formed.

4 pts

8. Identify the type of reaction that occurs when grilling a fish and explain why you selected that type of reaction.

4 pts



Figure 36. A fish cooking on a grill with steam being produced

GRADES:

A= 18 - 20

B= 15 - 17

C= 11-14

D= 6-10

F = 0-5

APPENDIX Q: PRE CHEMICAL REACTIONS GAMES
LIKERT SCALE SURVEY

Pre Chemical Reactions Games Likert Scale Survey

1. I enjoy playing content related games in class.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

2. I would be engaged in playing paper-based games (examples: escape rooms, who-dunnits, cards games).

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

3. I would be engaged playing computer-based games (examples: Nearpod, Blooket, Kahoot).

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

4. Do you prefer paper-based or computer-based games?

Circle the best answer:

Paper Computer No preference

5. I think playing games will help me understand the meaning of the terms and types of chemical reactions.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

6. I feel that learning through playing games helps me better comprehend vocabulary terms on assessments and may improve my grade.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

APPENDIX R: POST CHEMICAL REACTIONS GAMES
LIKERT SCALE SURVEY

Post Chemical Reactions Games Likert Scale Survey

1. I enjoyed playing content related games in class.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

2. I was engaged while playing the paper-based game (escape room).

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

3. I was engaged while playing the computer-based game (Blooket).

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

4. Did you prefer paper-based or computer-based games?

Circle the best answer:

Paper Computer No preference

5. Playing games helped me understand the meaning of the terms and types of chemical reactions.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

6. Playing games helped me to better comprehend vocabulary terms on my quiz and had a positive impact on my grade.

Circle the best answer:

Strongly Agree Agree Disagree Strongly Disagree

APPENDIX S: TEACHER OBSERVATION FORM-GAMES

Teacher Observation Form – Games

Table 5. Teachers' observations of student behavior will be entered on this form.

Student	Student is actively engaged.	Student is using terminology correctly in conversation and while asking questions.	Student is correctly identifying terms in games.	If a student makes mistakes, they are correcting them.
1				
2				
3				
4				
5				
6				
7				