Spring 2024

Timing Vocabulary Instruction for English Language Learners: Evaluating the Impact of Pre- Teaching vs. Post-Teaching Approaches on STEAM Comprehension

Askin Topal

Timing Vocabulary Instruction for English Language Learners: Evaluating the Impact of Pre-Teaching vs. Post-Teaching Approaches on STEAM Comprehension

An Action Research Project

Presented to

The Faculty of the Kalmanovitz School of Education

Saint Mary's College of California

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts in Education Administration

By

Aşkın Topal

Spring 2024

This action research project, written under the direction of the candidate's master's project advisory committee and approved by members of the committee, has been presented to and accepted by the faculty of the Kalmanovitz School of Education, in partial fulfillment of the requirements for the Master of Arts in Educational Administration degree.

______________________________ ______________
Candidate: Aşkın Topal Date

Master's Project Advisory Committee:

______________________________ ______________
Research Advisor: Heidimarie Rambo. Ph.D. Date

______________________________ ______________
Faculty Advisor: Tangela Blakley Reavis, Ph.D. Date

______________________________ ______________
Program Director: Tangela Blakley Reavis, Ph.D. Date

______________________________ ______________
Dean: Carol Ann Gittens, Ph.D. Date

Abstract

Timing Vocabulary Instruction for English Language Learners: Evaluating the Impact of Pre-Teaching vs. Post-Teaching Approaches on STEAM Comprehension
By
Aşkın Topal
Master of Arts in Educational Administration
Saint Mary's College of California, 2024
Heidimarie Rambo, Ph.D., Chair

This study investigated the effect of pre-teaching versus post-teaching vocabulary instruction among English language learners' (ELL) comprehension of STEAM vocabulary. The quasi-experimental study was conducted with two groups of ninth grade ELLs, where one group of students were taught vocabulary before content lessons, and the other group was taught vocabulary after content lessons. Data for the research were gathered through tests, quizzes, oral exams, and exit tickets. The results show minor differences in the means of these assessments between these two groups of students and suggest that the timing of vocabulary instruction is not a crucial factor for ELLs' success in STEAM. The data further suggest that vocabulary instruction may be influenced by students' prior experiences in science learning, especially those in their primary languages. Thus, the findings of this study confirm the findings of previous research (Bravo et al., 2007; Lee & Muncie, 2006; Townsend et al., 2012) that suggest ELLs need differentiated support during vocabulary instruction, as well as instructional strategies to activate their previous knowledge.

Acknowledgements

I extend my deepest gratitude to Dr. Heidimarie Rambo for her invaluable guidance, patience, and expert advice throughout the development of this thesis. Her dedication as a mentor profoundly shaped my research and academic growth, providing me with the skills and confidence to pursue my scholarly endeavors. Dr. Rambo's support was not just academic; it was a beacon of motivation that inspired me to strive for excellence in all aspects of my work.

Additionally, I am immensely thankful to Saint Mary's College for their unwavering support and understanding throughout my academic journey. Completing this thesis has been a formidable challenge, and the patience and flexibility afforded to me by the institution were crucial in allowing me the time needed to fulfill my academic commitments without compromise.

Table of Contents

Page

List of Figures

Figure

List of Tables

Table

Chapter I

Introduction

> In the beginning was the Word. And the Word was made flesh. It was so in the beginning, and it is so today. The language, the Word, carries within it the history, culture, the traditions, the very life of a people, the flesh. Language is people. We cannot even conceive of people without a language or a language without a people. The two are one and the same. To know one is to know the other. To love one is to love the other. (Dr. Sabine Ulibarrí, *El alma de la raza*, 1964)

I am an English Language Learner (ELL). I am a student whose native language is different from English. As an ELL and an educator, I have a unique perspective on the challenges faced by students whose native language differs from English. Throughout my teaching career, I have had the opportunity to instruct diverse student groups in various science subjects, including general and honors science classes for sixth, seventh, and eighth grade, Biology for ninth grade, advanced placement (AP) science for 10th grade, Chemistry for 11th grade, and Anatomy & Physiology and Physics for 12th grade. This action research study is not only an academic exploration of the subject but also a reflection of my personal experiences and a testament to my desire for growth in this area.

I arrived in this country at the age of 18 without any prior knowledge of English. Imagine finding yourself in a nation where you neither speak the language nor understand the cultural norms. Now, picture this individual student placed in a complex classroom setting within a typical school in the United States. In this environment, the student will encounter a new language and face customs and traditions that are vastly different from their own. This scenario mirrors my own experience, where I grappled with the simultaneous challenges of learning English and science content. Many of my students also face this challenge in my science classrooms. In each of my classes, there are English Language Learners (ELLs) from various parts of the world who must learn English and science concurrently.

Through this project, I tried to develop and refine pedagogical strategies that effectively address the diverse needs of ELLs at different proficiency levels within my classrooms and beyond. By conducting this research, I hope to contribute to the growing body of knowledge on best practices for supporting ELLs in their academic pursuits, ultimately fostering more inclusive and equitable learning environments.

The National Center for Education Statistics (NCES) lists the number of English Language Learners (ELLs) to be about 5 million in public schools throughout the nation in 2019-20 (NCES, 2020). English Language Learners (ELLs) are also considered one of the fastest-growing populations in our time (Short & Fitzsimmons, 2007). In every school throughout the United States, there is an expanding enrollment of students whose native language is not English (Hammer et al., 2014; Short & Fitzsimmons, 2007). Speedy growth raises essential concerns about whether states have assets (e.g., skilled instructors, language acquisition packages, curricula, and materials) and infrastructure to accommodate those students in their language instruction (Short & Fitzsimmons 2007). Not just my classroom but throughout the US, classrooms are filled with culturally-and-linguistically-different student populations whose reading, writing, critical thinking, and communication and argumentation skills all differ from one another.

"Academic English proficiency" refers to the ability to use English in an academic context (Hakuta et al. 2000). Also, academic language is very different from the basic language skills needed to survive in everyday life in school (Collier, 1987). English proficiency is needed to be successful at school and beyond. Furthermore, a student needs to know the key vocabulary in their science classroom to meet the requirements of the content being studied. The ability to understand and communicate science is an important skill not only for scientists but also for students (Baram-Tsabari & Osborne, 2015). Vocabulary knowledge, as defined by Wessels, refers to the ability to comprehend and use words effectively. It is crucial for understanding written texts. However, vocabulary knowledge is only truly beneficial when it builds upon and relates to the students' existing vocabulary and background knowledge (Wessels, 2013).

ELLs must do double the work of native English speakers to catch up with their peers (Short & Fitzsimmons, 2007). According to a study done by Collier (1987), ELLs require four to seven years of instruction to reach the average academic performance of native English speakers. The challenges ELLs face can make it seem as though they have to work twice as hard as native English speakers to achieve the same academic outcomes. ELLs are not only learning content in subjects like math, science, or social studies; but they are also concurrently learning the English language. To complicate that learning, ELLs might have had interrupted schooling or might come from educational systems that have different methods, curricula, or expectations than the one they are currently in. They might need to bridge the gaps in their previous understanding as they keep pace with the present content.

Many ELLs come from different cultural backgrounds. They may be unfamiliar with cultural references, idioms, or social norms that are taken for granted by their English-only peers. This can lead to misunderstandings or misinterpretations in the classroom. Most of my ELLs are entering the school with challenging academic skills at the same time that schools are emphasizing rigorous, standards-based curricula and assessments for next generation science standards (NGSS) for all students (Boyson & Short, 2003). Despite the lack of English language ability, ELLs are still placed in classes, such as science, with secondary teachers who may not be trained to teach basic literacy skills to their ELLs (Rueda & Garcia, 2001). The cognitive demands on ELLs are significant because translating information from English to their native language, processing it, and then translating their responses back into English in science class can be exhausting and time-consuming.

I strongly support the idea of learning English through content. ELLs can learn the language more effectively when English instruction is combined with content knowledge than they can in language-only classes (Chamot & O'Malley, 1994; Echevarria et al. 2004). When ELLs are encouraged to participate in scientific experiments, discussions, and writings, they are not only exposed to the critical thinking inherent in scientific inquiry but are also challenged to articulate complex ideas, hypotheses, and observations in English. This integrated approach not only enriches their academic journey but also prepares ELLs to navigate both the linguistic and scientific challenges in real-world contexts with confidence.

Statement of the Problem

I have been teaching various science classes to sixth through 12th graders over the last decade. Comprehending grade-level science vocabulary and using it correctly during lab practices has proven to be a very difficult task for many ELLs. I wondered how science teachers could best teach scientific vocabulary to ELLs who need to demonstrate the mastery of the content. In another words, is it more effective to pre-teach complex STEAM vocabulary to ELLs before covering the concepts, or to introduce the vocabulary terms after an initial exploration of the scientific ideas?

Purpose of Research

For ELLs who are navigating the intricate world of science education, the challenge extends beyond just understanding complex scientific concepts. They face the compounded difficulty of deciphering these concepts through the lens of a language they are still striving to master. Scientific jargon, inherently challenging even for native speakers, can appear overwhelmingly intricate for ELLs. This double layer of complexity – grappling with both the nuances of the English language and the intricacies of scientific phenomena – can inhibit their ability to fully engage with and internalize scientific knowledge. The purpose of this study is to speed up ELLs success rates in their science classrooms and beyond.

Action Research Question

The dual processing demands of language acquisition and scientific reasoning converge for ELLs in science classrooms and have implications for instruction. Therefore, the action research question for this study was: *How does the timing of STEAM vocabulary instruction, specifically pre-teaching versus post-teaching, impact ELLs' acquisition and application of STEAM vocabulary in high school science classrooms?* In particular, I wondered if ELLs in high school science classrooms would demonstrate better performance on vocabulary quizzes and science content assessments when STEAM (Science, Technology, Engineering, Art, and Math) vocabulary terms were introduced before lesson content compared to after lesson content?

Limitations

Doing action research while teaching is both enlightening and challenging. All academic undertakings have their set of limitations. By openly recognizing possible limitations, the researcher is better equipped to handle surprises, refine their methods, and ultimately, get closer to the truth they are seeking. Being clear about the limitations in my study isn't just about meeting academic standards; it's like being a smart explorer charting a course through unknown territory. Even though I have followed the guidelines for scientific research, I have to admit there are some limitations.

First, this research may not encapsulate the vast heterogeneity of ELLs. There are many aspects outside of school that are beyond the researcher's control, like where students come from or the kind of schooling they've had before, that can really change how well ELLs do in class. Every ELL brings their own unique mix to the classroom. This melting pot makes it tricky to pinpoint an approach that works for everyone. The group of ELLs in this study was highly diverse, each with their own language, culture, and educational background. Thus, the results of this study may not be transferable to other groups of ELLs, even those who seem to come from similar linguistic and cultural backgrounds.

Another constraint for this research is the time frame. A six-week study may not have been sufficient time to catch the full story of the students' learning journey. Such a short period may not allow for the full effect of instructional interventions to be observed. The breadth and depth of the analysis can be limited by this, leading to a narrower focus than what was originally intended.

Furthermore, when I asked students about how things were going in the science classroom, sometimes they might have said what they think I want to hear, not exactly what's really happening. While I was gathering data, I might not have been getting the whole story. Nevertheless, this study does give teachers some important clues, but it's like they're on a treasure hunt that's far from over. To really get what's going on with ELLs in science, teachers need to keep exploring, keep asking questions, and maybe follow their students' learning journeys for a longer time.

Assumptions

The core assumption of this action research is that within the field of science education, there is a unique combination of instructional practices and classroom environments that can substantially enhance ELLs' success rates. I also assumed that all students, regardless of their level of competency in the English language, were willing to put in the effort to master new science topics. Another belief was that these hands-on science experiments were effectively teaching students the content goals of the unit we were covering in class. The project also proceeded from the assumption that ELL students, when fully engaged and supported in their learning endeavors, will develop greater interest and enthusiasm in science, which in turn will lead to higher performance at all levels of their work. Besides providing a starting point for this inquiry, these assumptions also reflect my optimism and dedication to creating learning environments that are not only effective but also inclusive, regardless of students' backgrounds and abilities. Lastly, I assumed that my participants were responding truthfully to the various measurements, and they did so to the best of their ability.

Positionality of the Researcher

Not only does the researcher have their own personal history, but experiences may also play a determining role in shaping methodological decisions and interpretational techniques. The nuances in academic research results arise from the intersection between the researcher's educational life and the nature of the research specialty. In my thesis, which is about improving ELLs' performance in science classes, my own personal educational story and experiences play a significant role. They act as a compass, guiding my research question, my approach to the study, and the way I interpret the findings. As a researcher, I come from an ELL background, and this has largely shaped my understanding of this research. As a student striving to grasp complex scientific concepts while simultaneously learning complexities of English, I found that my own experiences closely mirror that of many of my current ELL students in science classes. My experience teaching science classes provides valuable insights not only from the perspective of those who have faced linguistic challenges, but also allows me to approach this issue with a researcher's lens, having witnessed firsthand the language-related obstacles and objectives ELL students encounter. It is not just a matter of understanding the learning experience; my role as both a former ELL student and a current science teacher enriches the research process. The challenges I overcame as an ELL have provided valuable insights that drive my progress. My past experiences serve as benchmarks for evaluating each new teaching strategy, granting me an intimate understanding of the obstacles ELLs encounter, including the areas where they need the most help. This personal connection highlights the importance of finding solutions and grounds my research in deep understanding and comprehensive knowledge. However, the research method still has its limitations, and these results are valid only within certain parameters. I've made a conscious effort throughout my research to ensure that my findings are not just subjective but also verifiable. This personal expertise, coupled with a systematic methodology, is my contribution to bringing a rich and comprehensive understanding to the field.

Definitions of Terms

Academic Language

Academic language refers to the formal language being used in schools varying from advanced vocabulary to complex language within academic disciplines (August et al., 2014).

Academic Language Proficiency

Academic language proficiency basically means being good at the language used in schools. It's about knowing the special words for different subjects, getting the hang of complicated grammar, and being able to talk or write the way they expect in classrooms (Bailey, 2007).

Academic Vocabulary

Academic vocabulary occupies a specialized position in the lexicon, residing between general service words of high frequency and more technical, field-specific terminology (Hirsh, 2012). For example, the complex *food chain* which sustains our *fauna* includes both *predator* and *prey* (Academic vocabulary is written in *italic*).

California Common Core State Standards

The California Common Core State Standards (CCSS) outline the K-12 educational criteria for subjects such as English language arts, Math, History, Science, and various technical disciplines. Their aim is to ensure students are equipped for both college and professional success by the time they finish high school (CDE, 2013).

Early Advanced

Students in the "Early Advanced" (EA) stage of language proficiency can use English in intricate scenarios and for learning across various subjects. They've honed their speaking and writing capabilities to summarize and engage in discussions with minimal mistakes that affect comprehension (CDE, 2016).

English Language Learner (ELL)

English Language Learners (ELLs) refers to a group of students who have specific needs as a result of cultural and linguistic differences (Snyder et al., 2016).

English Language Development

The California Department of Education defines this term as English language development through which English language learners (ELs) are expected to progress as they gain increasing proficiency in English as a new language (CA Department of Education, 2012).

Fluent English Proficient (FEP)

Fluent-English-Proficient (FEP) refers to students who are fluent-English-proficient and the students whose primary language is other than English and who have met the district criteria for determining proficiency in English (i.e., those students who were identified as FEP on initial identification and students redesignated from limited-English-proficient [LEP] or English learner (EL) to FEP (CA Dept. of Education, 2017).

English Language Proficiency Assessments for California (ELPAC)

The ELPAC is the required state test for English language proficiency (ELP) that must be given to students whose primary language is a language other than English. State and federal law require that local educational agencies administer a state test of ELP to eligible students in kindergarten through grade twelve (CA Dept. of Education, 2024).

Next Generation Science Standards

Next Generation Science Standards (NGSS) are an improved set of K-12 content standards outlining the expectations or what students should know and be able to do in science. (NGSS Lead States, 2013).

Reclassified Fluent English Proficient

A student labeled as Reclassified Fluent English Proficient (RFEP) was once identified as an English learner due to their primary language being other than English. Having demonstrated the essential English fluency skills, the student has since met the requirements and is no longer seen as an English learner (CDE, 2016).

Oral Language Proficiency

Oral language proficiency refers to students' proficiency in speaking and understanding spoken language (Mariëlle et al., 2016).

Scientific Explanation

When it comes to explaining concepts in science, there's a method scientists use. First, there is a claim, which is like the best guess answering a big "why" or "how" question. Then, there needs to be some solid evidence, which is all the data gathered to prove the guess isn't just a hunch (McNeill, 2006).

Implications

The results of this study, investigating how to make STEAM vocabulary resources for ELLs more effective, could greatly influence teaching methods as well as educational policy. The current research underscores the importance of words for making sense of and communicating about complex STEAM subjects where knowing an exact term often opens a door to understanding a concept. The research suggests that teachers can boost ELLs' access to STEAM curricula by pre-teaching vocabulary strategically. This corroborates the work done by Marzano on vocabulary acquisition as well as Cummins's distinction between discourse competence and academic language ability. Teaching language up front gives ELLs the tools they need; therefore, they are more likely to contribute actively to their own learning and apply new ideas to real situations. In addition, it highlights the necessity of methods that consider and use students' various intelligences, echoing Gardner's theory. Inother words, there is probably not a one-size-fits-all approach to teaching STEAM vocabulary for all ELL.

The results may also suggest a more inclusive educational approach is needed in schools. The educational system should be able to adapt to meet the varying needs of pupils. This means giving ELLs the support they need in environments that are traditionally considered difficult because of language barriers. Moreover, the study could inform policy decisions in schools and districts. Given evidence supporting pre-teaching vocabulary, schools might think seriously about using resources for comprehensive STEAM vocabulary programs which precede content. Additionally, these findings could impact behind-the-scenes faculty development programs, providing new educators with the proper training to better serve ELLs.

In summary, the implications of this study are that instruction in STEAM vocabulary instruction should be responsive and dynamic. It should strive to improve the academic outcomes for ELLs as well as to make school a place where there is an equal opportunity to learn for all students.

Chapter II

Literature Review

My action research was developed with the guidance of three major theorists. They are Lev Vygotsky (1978) who pioneered the concept of the zone of proximal development and emphasized the crucial role of social interaction in cognitive development, Michael Halliday (1973) who defined linguistics as the use of language to convey meaning, and Howard Gardner (2011) who helped educators understand that meaning conveyed in school classrooms can be presented in multiple modalities and can be demonstrated in multiple modalities, in relation to students' own multiple intelligences. Each theorist contributed to my hypothesis that high school science ELL students engaged in science classes could benefit from STEAM vocabulary instruction prior to content lesson, as opposed to students who receive STEAM vocabulary instruction post content lesson. Under each condition, students were afforded multiple ways to declare their learning, in accordance with Gardner's theory of multiple intelligences used in the classroom.

The inclusion of English Language Learners (ELLs) in mainstream science classrooms has been a topic of interest and research for several decades. As the number of ELLs continues to grow in schools in California, understanding their unique needs and challenges in science education becomes increasingly important. The most fundamental difficulty that ELLs face in science classrooms is the language barrier (Lee & Valdés, 2013). Even native English speakers may need additional support for understanding STEAM vocabulary effectively. But for ELLs, the problem gets more complicated as they work to master their English proficiency. According to Vygotsky (Vygotsky, 1978), language and cognition are deeply intertwined. Thus, while language barriers can present a difficulty, in the process of acquiring STEAM vocabulary ELLs can advance both linguistic and cognitive development.

This review of literature will explore how the ideas of some well-known educational theorists can direct efforts to raise the success rate of science classrooms for ELLs. For example, Vygotsky’s (1986) concept of the zone of proximal development suggests that learners can perform demanding tasks if provided with proper guidance (Vygotsky, 1986). Concerning ELLs and STEAM vocabulary, this is where pre-teaching plays its crucial role, consistent with the idea that language intervenes in knowledge acquisition. Bruner (1996) and Mercer (1995) have similarly emphasized the links between language and cognitive development in everyday life. Halliday contends that language does not stop at communicating; language is also necessary to make sense of the world (Halliday, 1978). This view reveals how vocabulary is so important in teaching STEAM subjects to ELLs. Cummins (2000) highlights the differences between everyday talk and academic language skills, suggesting that pre-teaching such vocabulary can enable ELLs to deal with the challenges of schoolwork by reinforcing their control over specialized language (Cummins, 2000). Gardner's multiple intelligences theory holds that each individual has different ways of learning (Gardner, 1983). As far as teaching STEAM vocabulary to ELLs, pre-teaching must respond to the variety of students' intelligences (Gardner, 1983). Pappamihiel (2002) makes a similar argument, noting that the broad backgrounds of ELLs require a diversity of strategies for instruction. Vygotsky's zone of proximal development underscores the importance of guided learning. Accordingly, in this action research project, I will draw on the foundational theories of these three researchers: Vygotsky's zone of proximal development which emphasizes guided learning, Halliday's systemic linguistic structure, showing that language is present within meaning, and Gardner's multiple intelligences which are relevant for pedagogical approaches that are not generalized. It is my goal to use these theories to strengthen my method for teaching ELLs to acquire STEAM vocabulary in the science classrooms. In addition, I will supplement my hypothesis with insights from recent studies to provide a modern context for its explanations.

Theoretical Rationale

The Zone of Proximal Development

Lev Vygotsky (1986), a scholar in sociolinguistics, developed theories that assigned language an influential role in thought. He postulated that humans can attain higher cognitive functions if assisted in a learning task by another person who was more knowledgeable than they were. His zone of proximal development (ZPD) represents the distance between what a learner can do without help and what they can do with guidance from a more skilled person. Vygotsky also introduced *scaffolding*, where a teacher can assist the learner within their comfort zone. Vygotsky’s foundational idea is particularly relevant in the context of ELLs and pre-teaching of STEAM vocabulary.

In STEAM subjects, vocabulary forms the bedrock of understanding in science. Concepts such as *kinetic energy*, *biodiversity*, or *algorithm* are far more than just words; they are complex ideas and processes. This makes things particularly difficult for ELLs: not only must they understand the scientific concept, but also negotiate the use of the English language. Here, Vygotsky's ZPD is more relevant than ever. If teachers pre-teach ELLs STEAM vocabulary, they are equipping them with the linguistic tools to tackle more complex material in their lessons. By doing so, teachers are aiding ELLs in bridging the gap between what they currently know and what they're capable of understanding with a little guidance. Activating ELLs’ prior knowledge is essential. For this reason, when they are equipped with the necessary STEAM vocabulary beforehand, ELLs can participate in activities confidently. Knowing the terms in advance makes them better able to express their thoughts, ask questions relevant to the point, and understand complex explanations.

Vygotsky also advanced the idea of the more knowledgeable other (MKO) where teachers or peers can serve as models for ELLs to learn new skills from within their zone of proximal development. The science classroom setting provides a perfect example of Vygotsky's MKO. When ELLs are taught STEAM vocabulary before the introduction to the content concepts, teachers can provide guidance and support for ELLs to gain confidence.

In conclusion, Vygotsky's theories provide powerful guidance for examining and improving teachers' approaches to teaching ELLs STEAM vocabulary. According to Vygotsky's ZPD theory, pre-teaching STEAM vocabulary may provide ELLs with the necessary support and guidance to push their understanding to higher levels. This practice will benefit ELLs through ZPD related teaching practices.

Systemic Functional Linguistics

The groundbreaking work of Michael Halliday in systemic functional linguistics (SFL) will be of particular value to teachers if it is put in the context of teaching ELLs in science classes. Halliday argues in SFL that language is the product of a social and cultural system (Halliday, 1994). This offers a valuable way for teachers to see language instruction for ELLs especially in STEAM vocabulary. This view can therefore be expressed as follows: Language is a representation of human experience (Halliday & Matthiessen, 2014). This represents the phenomenological variation in the world and the representational function of language comes with it, both being part of the ideational metafunction (Halliday & Matthiessen, 2014). The concept, *ideational metafunction* refers to the way language is used to represent experience and convey information about the world, including the people, objects, and circumstances we experience (Thompson, 2014). When one considers the descriptive nature of science – its aim to categorize, explain, and predict – the parallels between science instruction and the ideational function become evident. For ELLs, pre-teaching STEAM vocabulary serves as a bridge to these experiential concepts, enabling them to articulate and comprehend complex scientific phenomena. The science classroom is not merely an arena of descriptive discourse. It's a vibrant ecosystem where students, teachers, and sometimes even parents or community members interact. The interpersonal metafunction of language, which facilitates these interactions, is of paramount importance (Halliday, 1978). By ensuring ELLs are familiar with key STEAM vocabulary prior to instructional content, it provides them the linguistic tools required for active participation. This proactive approach ensures that students are not passive recipients but active constructors of knowledge, a principle Halliday advocated for. The textual metafunction, focusing on the organization of discourse, cannot be overlooked, especially when navigating the often-intricate terrain of scientific discourse (Halliday & Hasan, 1985). Science often demands a sequential presentation of facts, from foundational concepts to more advanced hypotheses. Familiarity with foundational vocabulary allows ELLs to discern the flow of lessons, link interconnected ideas, and actively engage in the learning process. Another significant contribution of Halliday's is the concept of "register" (Halliday, 1978). In essence, every discipline, including the various branches within STEAM, has its unique linguistic fingerprint. Whether it's the probabilistic language of mathematics or the observational lexicon of biology, each domain demands a nuanced linguistic approach. Pre-teaching vocabulary can serve as a primer, helping ELLs become aware of these distinct registers. This teaching process not only enhances students' understanding but also bolsters their confidence, enabling them to better access different STEAM subjects.

Halliday's concept of thematic progression provides a methodical framework for disseminating information that is centered entirely on the communication of links between clauses--not just information transmission by means of context words or by other means (Halliday & Matthiessen, 2014). Science communication requires moving up the topic ladder in an orderly fashion, making sure all the key ideas are taken care of. By mastering the STEAM vocabulary, ELLs can now follow instructional discourse more adeptly.

ELLs need to learn the STEAM vocabulary in order to participate appropriately, whether they are interpreting, inventing, criticizing, or rejecting science concepts. Halliday's SFL presents a solid theoretical base from which teachers can teach ELLs STEAM vocabulary. Applying Halliday's concepts can help teachers form a more comprehensive and effective strategy for teaching ELLs. In my research, I stress the heuristic and representational functions of language in relation to STEAM vocabulary. The heuristic function is particularly applicable to ELLs. As they cope with STEAM subjects, their prior evaluations of environmental relationships must be corrected and refined. This re-thinking and re-learning process demands repetition until the new concepts are grasped thoroughly in terms of language. Pre-teaching STEAM vocabulary may allow ELLs to have an easier time making these changes intelligently.

The representational function of language, on the other hand, comes especially to the forefront in the classroom where teachers carry out their direct teaching. Explicitly teaching and supplying ELLs with the vocabulary specific to STEAM subjects allows teachers to better represent and convey the core concepts and experiences within those content areas, making the material more comprehensible for their ELL students (Anstrom et al., 2010; Zwiers, 2008).

Classrooms that teach STEAM subjects are not only about learning dry facts but also practicing observation, forming hypotheses, conducting experiments together, and coming up with theories about the world we live in. Before ELLs begin practicing these steps for the first time, they may benefit from having language skills ready both for the heuristic and representational parts of STEAM education.

Multiple Intelligences

In his groundbreaking work on multiple intelligences theory, Howard Gardner suggested that individuals have many facets of intelligence--not a single, unified ability (Gardner, 1983). Gardner's theory encompasses linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic, intrapersonal, and interpersonal domains of intelligence. In the context of ELLs in science classrooms, Gardner's work suggests a strong rationale for pre-teaching STEAM vocabulary. Linguistic intelligence, as Gardner identified it, involves one's ability to manage languages and manipulate words in such a way that a person can express broad ideas (Gardner, 1983). It's not just about speaking or writing; it's about understanding and interpreting linguistic subtleties. For ELLs, the linguistic territory can be troublesome because they must acquire words and other terms related to STEAM subjects, as well as learning a new language. Pre-teaching STEAM vocabulary bolsters the linguistic intelligence of ELLs so that they possess a solid grounding, upon which they can build, analyze, and understand scientific material. Furthermore, the logical-mathematical intelligence, referring to the ability of logical thinkers (Gardner ,1983), is deeply embedded in STEAM subjects. Acquiring STEAM vocabulary may allow ELLs to see patterns in the data, draw conclusions, and engage in problem-solving actively in science classrooms. When students are pre-taught a variety of STEAM vocabulary words, they are better equipped to identify logical sequences, formulate hypotheses, and understand experiments, thereby enhancing their logical-mathematical intelligence. Spatial intelligence, another concept highlighted by Gardner, involves the ability to grasp the world as it truly is--and then to remake or change one's perceptions in order to fit their needs (Gardner, 1999). In science classrooms, this often implies understanding graphs, diagrams, models, in other words, visual representations of data. When learners have been pre-taught STEAM vocabulary, even though it is just a tool for them, they are in a better position to decode visual information and internalize it within the context of what is said linguistically during lessons. Further, being able to communicate understanding is part of the interpersonal intelligence Gardner (Gardner, 1999) talks about. In the context of science, working and cooperating. At times whole class periods are spent on laboratory group activity. For ELLs, socializing, discussing theories, and collaborating with peers are more fruitful it they have foundational STEAM vocabulary comprehension. This not only assist them in getting to know the subjects under the learning goals, it also fosters a sense of community. For those ELL students who have strengths in a particular intelligence, teachers then can tweak their curriculum to match it; thus, ensuring that pre-teaching vocabulary does not just serve as an extension but an essential part of teaching that supports the student's multiple intelligences.

Vygotsky's sociocultural theory stresses the connection between language and thought and maintains that more effective learning occurs in the ZPD when students interact with an MKO (Vygotsky, 1978). Pre-teaching STEAM vocabulary can be an important tool in the context of ELLs in science classrooms. In this way, teachers elevate students' ZPD, so that they can get a better handle on difficult STEAM concepts through the help of a peer or teacher acting as their MKO. For instance, if an ELL student is pre-taught the term *photosynthesis*, when the concept is introduced in class, they can more easily bridge the gap between their existing knowledge and the new information, benefiting from discussions and collaborative exercises.

Michael Halliday's systemic functional linguistics underscores the critical roles language plays, especially its heuristic and representational functions (Halliday, 2004). Within the science classroom, ELLs continually reshape their understandings of STEAM concepts (heuristic) while also acquiring and conveying facts (representational). By pre-teaching STEAM vocabulary, educators facilitate ELLs in their exploration and understanding of new content, ensuring that when they encounter a new word like "evaporation" in a text, they can both comprehend its meaning and relate it to their observations, such as watching water vanish from a heated beaker.

Lastly, Howard Gardner's theory of multiple intelligences offers a unique perspective, emphasizing the diverse ways students learn and understand (Gardner, 1983). By pre-teaching STEAM vocabulary, educators can cater to the various intelligences ELLs possess, from linguistic to spatial. For instance, when introducing the term "photosynthesis," teachers can provide both verbal explanations and visual diagrams to describe what it is. This dual way of explanation may help ELLs with strong linguistic intelligence to understand the term, while those with stronger visual learning abilities can understand through the illustration, making sure everyone has a unique learning experience.

Review of Related Research

Supporting ELLs in Developing STEAM Vocabulary Instruction

ELLs often face multiple challenges in mastering specialized vocabulary within the STEAM subjects. Pre-teaching vocabulary is emerging as an impactful method in facilitating comprehension and bolstering ELLs' active participation in lessons, especially when aligned with the Next Generation Science Standards (NGSS). According to Vygotsky's sociocultural theory, social interactions play an important role in the learning process. Within this pedagogical framework, the zone of proximal development (ZPD) becomes a pivotal concept. With effective scaffolding, as highlighted by Wood et al. (1976), ELLs can transcend their independent learning capabilities, anchoring complex STEAM terms in meaningful cultural and scientific contexts. NGSS offers performance expectations, stressing what students should be able to do, rather than what they should know (NGSS Lead States, 2013). For instance, while learning about ecosystems, a performance expectation might be: "Construct an argument that some animals form groups to help members survive." To meet such expectations, ELLs must not only grasp the scientific concept but also the vocabulary, like *ecosystems*, *construct*, and *argument*. People who advocate for pre-teaching STEAM vocabulary point out that this strategy equips ELLs with the necessary linguistic tools to meet and even surpass these performance expectations. Numerous educational scholars have stressed the advantages of pre-teaching vocabulary. Stahl and Fairbanks (1986), for example, have emphasized that vocabulary knowledge is crucial for reading comprehension, and pre-teaching can facilitate smoother integration into texts.

Vocabulary Acquisition and Content Mastery

Robert J. Marzano's research focuses on the importance of direct vocabulary instruction as a way to improve student achievement. Based on their research, Marzano and Pickering state that effective vocabulary instruction, including techniques like semantic mapping and non-linguistic representations, can lead to significant gains in content mastery (Marzano & Pickering, 2005). In terms of building STEAM vocabulary, Marzano's work highlights the essential role of vocabulary in understanding difficult concepts and the need for explicit vocabulary instruction for ELLs. Marzano's research suggests that, in general, pre-teaching vocabulary can enhance content mastery (Marzano & Pickering, 2005).

From García's (2009) perspective, drawing on ELLs' full linguistic language before explicit vocabulary instruction could boost comprehension. In the context of STEAM vocabulary instruction, García's work implies that allowing ELLs to initially grapple with new concepts by leveraging their entire linguistic repertoire can enhance their comprehension and retention. This approach recognizes the cognitive richness of ELLs and creates opportunities for learners to anchor new terminology in familiar linguistic contexts before explicit vocabulary instruction occurs.

Similarly, Isabel Beck's work on robust vocabulary instruction further supports the general approach to move beyond memorization and instead focus on active engagement and contextualization of words, especially for ELLs dealing with complex, content-specific or tier 3 vocabulary like STEAM terms (Beck et al., 2002). This could argue for post-teaching vocabulary after an initial conceptual encounter. Beck introduced the idea of tiered vocabulary, categorizing words into three tiers based on their complexity and utility. For STEAM education, where vocabulary ranges from commonly used words (Tier 1) to highly specialized jargon (Tier 3), this tiered framework provides a structure for tailoring instruction to ELLs' specific needs. By first exposing learners to STEAM concepts through hands-on activities or real-world examples, and then following up with explicit vocabulary instruction, educators can leverage the contextualization and active engagement that Beck advocates for.

Larsen-Freeman's research on complexity, accuracy, and fluency in language learning concludes the importance of balancing these three dimensions when teaching vocabulary (Larsen-Freeman, 2018). For STEAM vocabulary, pre-teaching could enhance accuracy while post-teaching might better develop fluency. Her research findings stress the interconnectedness of three dimensions: complexity, accuracy, and fluency. Focusing on one at the expense of the others might not yield holistic language development (Larsen-Freeman, 2018). Thus, while pre-teaching vocabulary, teachers should integrate activities that cater to complexity, accuracy, and fluency alike.

Finally, Gibbons' work on scaffolding language and content highlights how teaching vocabulary can serve as an important scaffold for ELLs (Gibbons, 2002). Pauline Gibbons researched the intersection of language and content instruction, particularly in ELLs' classrooms. She emphasizes the need for active classroom discourse, which could be facilitated by post-teaching vocabulary within content-rich contexts. For STEAM educators, this translates to a more interactive approach to teaching vocabulary, where students are actively using and discussing terms in context. Her research findings suggest that for ELLs dealing with STEAM vocabulary, a blend of direct instruction and collaborative exploration is most effective. Gibbons' work on scaffolding suggests the need for robust classroom discourse around vocabulary, enabling dynamic negotiation of word meanings as variability in acquisition occurs with either sequencing approach (Gibbons, 2002). She emphasizes the importance of scaffolding and classroom discourse for integrating language and content instruction (Gibbons, 2002). For teaching STEAM vocabulary, this indicates an interactive approach where students actively use and discuss terms in meaningful contexts with appropriate support.

Bilingualism and Language Learning

Jim Cummins' work on bilingualism and language learning offers valuable insights into the distinction between Basic Interpersonal Communicative Skills (BICS) and Cognitive Academic Language Proficiency (CALP). While ELLs may develop conversational fluency relatively quickly, academic language proficiency, including subject-specific vocabulary like STEAM terms, requires more extended support and instruction (Cummins, 1984). Through both quantitative and qualitative methods, Cummins explored the cognitive advantages of bilingualism and the role of language proficiency in academic outcomes. I will explore Cummins' suggestions in regard to my study, particularly focusing on how his findings relate to the acquisition of STEAM vocabulary among ELLs.

Variability in Second Language Acquisition

Elaine Tarone's research on variability in second language acquisition introduces the concept of interlanguage, which refers to the transitional state learners experience as they move from their native language structures to the target language structures (Tarone, 2009). When it comes to learning STEAM vocabulary, Tarone’s research highlights the need for teachers to recognize and accommodate the fluid nature of language acquisition, providing continuous support and feedback to help ELLs stabilize their understanding of STEAM terminology.

Lyster's findings on corrective feedback suggest that if vocabulary is post-taught after an initial conceptual exposure, explicit vocabulary feedback may be most beneficial when learner makes a mistake (Lyster, 2007). However, Larsen-Freeman's work highlights the importance of balancing accuracy, complexity, and fluency when teaching vocabulary (Larsen-Freeman, 2018). A pre-teaching approach focused on accuracy of STEAM terms could complement a post-teaching emphasis on fluency. Effective instruction must account for this by providing continuous feedback, balancing accuracy, and fluency goals, leveraging teacher expertise in multilingual language acquisition (de Jong, 2011), and facilitating an interactive classroom environment that supports the negotiation of vocabulary meanings (Gibbons, 2002).

De Jong's research on foundations of multilingualism highlights the pivotal role of teacher preparedness in effectively scaffolding and providing feedback as ELLs navigate the variable process of acquiring new vocabulary, whether pre-taught or encountered naturally through content (de Jong, 2011).

Summary

The research reviewed in this study provides a foundation for understanding the importance of STEAM vocabulary instruction for ELLs and the potential impact of sequencing this instruction. While some studies suggest the benefits of pre-teaching vocabulary to facilitate content comprehension, others highlight the advantages of integrating vocabulary instruction within meaningful, content-rich contexts. This literature review stresses the need for further research to explore the most effective strategies teaching STEAM vocabulary to ELLs.

Some researchers like Marzano and Gibbons suggest pre-teaching vocabulary can provide an important comprehension scaffold for ELLs as they encounter complex STEAM content (Marzano & Pickering, 2005; Gibbons, 2002). Having this prior knowledge of key terms may help them better understand the concepts being taught. However, others like García and Beck argue for a more contextualized, post-teaching approach (García, 2009; Beck et al., 2002). Allowing ELLs to first deal with hands-on activities or real-world examples of the STEAM concepts can create an authentic need to learn the vocabulary. Post-teaching then provides explicit instruction after this initial exposure.

Cummins' work indicates pre-teaching aligns with the need for extended scaffolding of academic language for ELLs (Cummins, 1984). But he also emphasizes positioning ELLs as capable learners, which fits with post-teaching models (Cummins, 2000). Researchers like Krashen (1982), Genesee (2005), and Slavin and Cheung (2005) don't directly prescribe a sequence, but their findings highlight integrating vocabulary with other language components like reading, phonics, and fluency development.

Across the literature, common themes emerge - the importance of classroom discourse (de Jong, 2011), continuous feedback (Tarone, 2009; Lyster, 2007), and connecting vocabulary to meaningful contexts (Thomas & Collier, 2002). An effective approach may involve strategically combining pre-teaching of key terms with ample opportunities for contextualized practice, negotiating word meanings, and integrating vocabulary across language skills.

Eventually, the research suggests the sequencing choice should depend on factors like ELLs' proficiency levels, the specific STEAM concepts being taught, and how vocabulary instruction connects to broader language development goals. The research literature presents different viewpoints on when to introduce STEAM vocabulary to ELLs, including before the content lesson (pre-teaching) or after the initial concept has been explored (post-teaching). The following chapter outlines the specific methods for gathering and analyzing data that will guide my examination of STEAM vocabulary sequencing through practical classroom implementation with ELL students.

Chapter III

Methods

This action research project explored effective STEAM vocabulary instruction for ELLs, with a personal touch. Although no longer a designated ELL student, I was once, and I have first-hand knowledge about the many challenges entailed in learning a new language as one grapples with the complexities of academic content in that language. Although I have drawn on Vygotsky's social constructivism, Gardner's multiple intelligences, and Halliday's systemic functional linguistics, this study is also based on my practical experiences and understanding of ELL environments. Through the lens of these three theoretical frameworks, the research considered when to teach STEAM vocabulary in relation to the STEAM content to ELLs. The study, in the wake of influential educational theorists such as Cummins, Marzano, and Beck, sought not only clarify but also offer ways for ELL students to better understand and participate more in classroom-based learning.

Propelled by my own history as an ELL student and informed by the insights of well-known educational researchers, my method examines the proposition that pre-teaching of STEAM vocabulary can lead to increases in comprehension and interaction with science among ELLs. Cummins (1981) does important theoretical work concerning bilingual education and holds that bilingualism has cognitive advantages. He suggests that language proficiency is the key to all-around academics in different subjects, including STEAM. This study is consistent with strong emphasis on vocabulary as the key to academic achievement, indicating that a good grasp of vocabulary can promote better understanding of complex STEAM concepts.

Gibbons (2002) further argued the case for language and content integration: language instruction should not be done in isolation from content teaching. This idea fit with my intention that, to bridge the gap between language proficiency and understanding of materials, STEAM vocabulary should be introduced before lessons. Marzano (2009) in his expansion on language and content learning, especially research on the enhancement of vocabulary acquisition, insists on contextual learning. Fitting neatly with his findings is the practice of contextualizing vocabulary in the context of STEAM subjects because contextualized vocabulary instruction improves memory and comprehension. Moreover, Cummins (2000), who notes that language plays an important role in academic success, suggests that vocabulary teaching tied to content learning can make it easier for ELLs to grasp complex STEAM concepts. It's not just about teaching words but about building bridges between language and complex conceptual ideas.

The research also benefited from Genesee's (1994) conclusions about integrating language and content, arguing that when ELLs are exposed to words in context, ELLs are not just learning another language but also enriching understanding. This work is further informed by Thomas and Collier (2002) on bilingual education, which indicates the truly transformative power of programmatic language instruction in enhancing cognitive abilities among ELLs. According to the hypothesis of my study, a structured approach to vocabulary instruction will have a significant impact on ELL comprehension and engagement with STEAM subjects. Here, too, drawing from Krashen's (1982) theory of second language acquisition, this paper will explore how ELLs can create an optimal environment for learning by presenting and studying vocabulary in relation to real-world contexts.

Research on pre-teaching and post-teaching vocabulary to ELLs in STEAM education still needs to define these concepts more clearly. Pre-teaching vocabulary involves introducing and explaining key terms before starting the lesson's content, aiming to provide a foundational understanding that students can build upon. In contrast, post-teaching vocabulary introduces terms after students have encountered the concepts in a practical context, theoretically allowing them to connect terms directly with their hands-on experiences. This study sought to understand if introducing vocabulary before STEAM lessons (pre-teaching) is more effective than introducing it afterward (post-teaching) in enhancing ELL students' comprehension and engagement in science classes.

Setting

Adopting a quasi-experimental design, this study was conducted in two similar ninth-grade science classes in an urban high school, with a significant proportion of ELL students. Class A, with 20 students, eight of whom were ELLs) received the intervention of pre-teaching vocabulary, whereas Class B, with 19 students also including eight ELLs, followed the approach of post-lesson vocabulary instruction. Bay Area Technology School (Bay Tech) in the East Bay region of northern California is a charter school with a culturally-diverse student body of 350 pupils. The school's population predominantly consists of Latinx students, who make up 65.0% of the student body, reflecting a vibrant Latino culture and influence in the school community. African American students form the second-largest group at 24.9%, adding to the school's diverse culture. The representation of Asian students stands at 1.4%, alongside a similar percentage for Caucasian students, contributing to the school's multicultural environment. Proficiency levels for reading are 22%; for math, only 12%. We see plenty of room for improvement here. Nonetheless, the school's average graduation rate is 90%. Most teachers at Bay Tech are employed in full-time positions, while three administrators and four full-time clerical staff provide service to students coming from different parts of the city.

Procedures

Vocabulary First Approach

In the Vocabulary First Approach, content-specific vocabulary terms associated with the unit on ecosystems were presented at the outset of each lesson during the implementation stage. Students began with word-based activities such as guessing meanings, coming up with definitions, and using the words in sentences of their own. This vocabulary-focused start was followed by a series of talks on STEAM subject, and ending in a lesson where everyone did hands-on coursework applying the terms they had just learned. The Vocabulary-First Approach aligns with the work of Marzano (2009) and Beck (2013) and follows their argument that pre-exposure to key terms can raise a student's comprehension as instruction becomes more sophisticated and as students participate in labs. Based on the theory and research of Marzano and Beck, as well as Gibbons (2002) and Cummins (2000), I anticipated that students would not only show greater mastery of the STEAM vocabulary but also attain a more profound knowledge of the scientific ideas being taught. This is based on the notion that as a bridge to understanding new information, pre-teaching vocabulary makes the STEAM content easier and more comprehensible for learners.

The learning goal was to get students accustomed to the vocabulary needed to talk about ecosystems. Students were introduced to words like *biodiversity* and *photosynthesis* by soliciting student guesses about what these content-specific words connote. After refining their definitions, these were reinforced with a matching game and a lecture full of real-world examples. After that, students were guided to use some of these words in their own writing through lab reports. To conclude the lesson, I reviewed the major points and asked students to spend a moment reflecting on how getting the STEAM vocabulary first may have clarified their understating, before writing down their reflections in a few sentences in their journals. At the end of the week, a general examination was given in order to assess student learning.

Vocabulary Last Approach

The instructional sequence for this group was intentionally reversed, placing the introduction of vocabulary after the lecture and lab sessions. This structure allows students to first grapple with new concepts in a hands-on, practical manner during the lecture and lab. Only after this initial exposure were they introduced to the specific vocabulary terms, engaging in activities similar to those of the first group, such as defining and using the terms in context. The Vocabulary-Last Approach was influenced by the work of Larsen-Freeman (2001) and Tarone (2005), and is based on the premise that concepts are better learned in a practical setting before content-specific vocabulary is encountered. The hypothesis underlying this approach is that students who have participated in hands-on activities will not forget STEAM vocabulary as easily as those who have not. This hypothesis is backed up by the work of Genesee (1994) and Lyster (2007), who claim that encountering vocabulary lists only after seeing them used regularly in practical work helps students relate more directly these terms to things they have seen and discovered in class, thus facilitating their grasp and recall of the material as a whole.

The second group of ninth-grade science students will also study ecosystems. First, they were exposed to a lecture on ecosystems. This was followed by 30 minutes in the lab, where students completed hands-on experiments. In some of these activities, the workings of ecosystems were observed; some are added by humans--an experimental, unplanned network that is compared to different habitats. In each of the experiments, the goal was for students to see science in action. After the lecture and lab work, I introduced terms like *biodiversity* and *photosynthesis*. We went over each vocabulary term to link it back to the lab they had completed.

This was followed by vocabulary-focused activities similar to those completed with the first group of students. After a short summative review, students were asked to write down any thoughts about how hands-on learning helped them understand the material. In the course of these hands-on experiences -- these moments of discovery and enlightenment -- students may have experienced a sense of mastery of the STEAM vocabulary.

Implementation

Prior to initiating my study, I obtained approval from the school principal. The study aimed to evaluate the impact of two different vocabulary instruction sequences – Vocabulary-First and Vocabulary-Last – on the comprehension of STEAM subjects among ninth-grade ELL students. Baseline testing was undertaken in October through a sequence of common standard exams, yielding an initial starting point.

For about six weeks starting in November, I split the research into two approaches. In Group A, I started each class by introducing some key STEAM vocabulary. The students first guessed the meanings, then wrote their own definitions, and finally, they tried using these words in sentences. After this vocabulary introduction, we moved on to the lecture about the STEAM topic and a practical lab session where students applied the vocabulary. This method aligns with Marzano’s and Beck's recommendations on the benefits of introducing vocabulary before the main lesson to enhance comprehension. Meanwhile, Group B did the reverse. They first attended the lecture and participated in the lab, getting a hands-on experience with the STEAM concepts. Only after this practical introduction were the vocabulary terms introduced. This approach was based on theories suggesting that learning words after experiencing their practical application leads to more meaningful understanding. The specific vocabulary items were taught only after these activities so that students could relate the terms to their firsthand experience. This method is consistent with the educational theories of Larsen-Freeman (2001) and Tarone (2005), both of which call for a vocabulary learning approach in a context of use.

Data Collection Methods

ELLs' understanding of STEAM concepts were measured through vocabulary tests, classroom observations, and student reflective journaling. To ensure equitable comparison between the effectiveness of each instructional approach, I used the same set of assessments for Group A and Group B. These assessments were set up in line with the ideas of authors like Cummins (2000) and Genesee (1994), who suggested not only simple memorization but also the application and comprehension of key STEAM concepts through contextual learning. The data collected from these assessments can provide a reliable reflection of ELLs' understanding because it is closely related to the content and vocabulary learned in class. This method of evaluation supports the reliability and validity of the research findings, in line with educational research standards such as those contained in work by Thomas and Collier (2012) and Slavin and Cheung (2011).

Vocabulary tests were used to explore ELLs' learning of the STEAM topic, ecosystems. In order to ensure comparability between the two groups, the Group A and the Group B are both given the same tests. Based on Beck (2013) and Marzano (2009), the composition of these tests was similar, focusing not only on vocabulary recall but also practical application within sentences. With this approach, the gathered data accurately reflected understanding among students. By testing vocabulary in its practical uses, the tests help track how well vocabulary has been integrated into overall learning, regardless of the instructional approach. In these tests, students were not expected just to recite words, but to show that they understood them by using them effectively in context. This approach ensured that the tests assess not just the students' ability to recall vocabulary but also the extent to which these words can be used in a meaningful, practical way, which may reveal a deeper understanding of vocabularies in the context of STEAM disciplines.

To test the effectiveness of pre-teaching and post-teaching vocabulary strategies for ELLs' STEAM vocabulary acquisition, I wanted to a balance of qualitative and quantitative evidence. Therefore, in addition to vocabulary texts, I also collected data through classroom observation. I paid close attention to ELLs' progress, monitoring their engagement, and listening closely to their language. I tried to observe consistently with both Group A, and Group B. I hoped to see whether students were capable of using new STEAM vocabulary in a real-time discussion, and how well they demonstrated their understanding of the words. According to Lyster (2007), corrective feedback shows that the interaction and participation in classrooms are key factors in language learning. Small group discussions gave opportunities to use vocabulary in specific conversational contexts, taking up Cummins' (2000) distinction between basic interpersonal communicative skills and cognitive academic language proficiency. By looking at these dynamics, I attempted to discern whether there were learning outcomes differences as a result of the different vocabulary instruction approaches. How students use words and ideas spontaneously in group activities or discussions provided living examples of these concepts.

Students also completed reflective learning journals because these may give insights that correspond with Vygotsky's emphasis on self-reflection and cognitive and language development. ELLs' personal accounts of how they acquired STEAM vocabulary may show not only their attitudes but also information about how effective the strategies really are in practice.

By incorporating both qualitative and quantitative methods, these tests generate a comprehensive set of data about the interplay between verbal understanding and subject matter acquisition in STEAM education for ELLs. Each of the performance tasks were graded using a rubric modeled on Gibbons' (2002) theories, which assess a person's capacity for using language in context, not just their content knowledge, across various formats such as written work and presentations.

Plan for Data Analysis

The plan for data analysis integrated principles laid out by key educational theorists and researchers. First, for the quantitative data derived from student assessments and vocabulary tests, I used statistical methods. This included calculating mean scores and standard deviations in order to compare the performance of students in Group A vs. Group B. Quantitative analysis is also vital for objectively measuring the effect on students' awareness of STEAM phenomena and their retention of vocabulary. This aligns with Marzano's (2009) emphasis on content mastery rather than performance and Beck's (2013) robust vocabulary instruction model. As for the qualitative data from classroom observations, a thematic analysis will take place. This analysis, based on the work of Lyster (2007), will involve coding responses and observations to look for patterns or themes that emerged, particularly focusing on student engagement and attitudes towards STEAM vocabulary. This method is important for capturing the nuanced experiences and perspectives of ELLs, adding depth and context to the quantitative results. This mixed-method approach, which combines the objectivity of statistical analysis with the depth of qualitative insights, represents the comprehensive assessment approach advocated by Cummins (2000) and Gibbons (2002). Both emphasize that language learning must be integrated with teaching about its substance. Ultimately, this study sought to provide a detailed, evidence-based comparison between Group A and Group B to better understand how to effectively teach the vocabulary for STEAM classrooms.

Summary

Teaching STEAM vocabulary to ELLs presents a unique set of challenges, particularly concerning strategies for teaching vocabulary before or after a lesson. This research explored the effects of these two teaching methods have on ELLs' learning outcomes in STEAM education. Pre-teaching vocabulary involves teaching relevant terms and concepts before students engage with a lesson. This approach is derived from Vygotsky's theory of the Zone of Proximal Development; “As Hiebert and Kamil (2005, 17) state, ‘learning is most effective when students are given support at a level just above their current level of competence’". For ELLs, pre-teaching vocabulary might pave the way by giving students a stepping-stone of support upon which new knowledge can be built.

Post-teaching involves introducing vocabulary definitions in conjunction with the terms only after they have been covered in context; this approach might help students connect vocabulary to its application, much like a tool interacts with a material. It can reinforce learning through experience and support students in making the connections between vocabulary and practical uses. Post-teaching lets ELLs first interact with the content intuitively and then come to understand the language that describes it. This may help ELLs with deeper conceptual comprehension of the material.

This research aimed to provide evidence for how to best teach EL students in language-enriched STEAM classrooms. The study aimed to accurately measure the impact of teaching vocabulary before and after content lessons on ELLs’ performance in STEAM subjects. A mix of student assessments, vocabulary tests, and classroom observations was employed to provide both quantitative and qualitative data. This approach aligns with the pedagogical principles advocated by Beck (2013) and Cummins (2000) while also addressing gaps in the existing literature, as highlighted by Genesee (2005) and Reuda and García (2001).

My thesis took a look at these educational practices from the perspective of integrating STEAM education and teaching ELLs what they need to know at grade level. Researching both viewpoints aims to offer a more comprehensive picture with respect to STEAM vocabulary and how they affect ELLs' success in scientific education. However, each method has its own drawbacks. If pre-teaching is linked with passive learning, it may only produce a superficial understanding. Students may memorize terms while remaining ignorant of how they can be used properly. Conversely, language barriers could make post-teaching difficult for ELLs. This method takes for granted a level of language skill in ELLs that they may not have, which will likely cause them confusion or frustration. Pre-teaching gives students an initial supply of language that allows them to better understand new knowledge, but post-teaching reinforces this learning with concrete examples and contextual logic.

Chapter 4 will report the outcomes of the study, including the performance and vocabulary acquisition of the two groups of ELL students who underwent different instructional approaches. The chapter will discuss the effectiveness of pre-teaching versus post-teaching STEAM vocabulary strategies by comparing assessment results, including multiple-choice questions, vocabulary match quizzes, grading rubrics, and exit tickets. The findings will show how each instructional approach impacted the students' understanding and retention of STEAM vocabulary.

Chapter IV

Findings

The purpose of my action research was to explore whether pre-teaching or post-teaching vocabulary was more effective in helping ELLs communicate their understanding of STEAM subjects. This chapter compares the results of my study between the two vocabulary instruction methods on student understanding and recall of STEAM vocabulary. This research draws on Lev Vygotsky's work, and his core concepts of ZPD. In line with the ZPD, Vygotsky (1986) emphasized the central role of language in cognitive development, arguing that learning is most powerful in the ZPD under the guidance of those with more knowledgeable others. In addition, my research is grounded in Michael Halliday's (1973) systemic functional linguistics (SFL) framework which proposes that language serves to make meaning and that these meanings are functional in that they serve to allow students to interact with meanings (i.e., meanings of STEAM vocabulary content with those of informational texts).

This theoretical perspective has served to frame explorations of the ways in which vocabulary teaching may shape how ELLs engage with complex scientific concepts as they read to 'learn' (i.e., gain new information or enhance comprehension). My research also draws on Howard Gardner's (2011) theory of multiple intelligences which proposes that individuals learn in a range of ways and process information differently. Gardner (2011) noted that there are various types of intelligence including linguistic and logical-mathematical intelligences that are likely involved in the context of STEAM vocabulary instruction for ELLs.

My research methodology and approach are further informed by several influential scholars in language acquisition and STEAM education. Marzano (2009) identified effective research-based vocabulary teaching strategies such as reinforcing new terminology, using terms in context, relating words to students' background knowledge, and incorporating visuals. All of these strategies can support ELLs in a pre- or post-teaching framework. Specifically, Marzano determined that vocabulary should be taught before and after new content lessons using complementary vocabulary activities to maximize student understanding and retention which aligns with the idea of this thesis study exploring ideal sequencing. Beck (2013) developed a three-tiered approach to identifying key vocabulary words in texts and planning targeted instruction, emphasizing that teaching definitions, context uses, and engaging students to process new terms facilitates learning regardless of whether applied before or after lessons. Specifically, Beck focused on the importance of repetition and giving students multiple meaningful exposures to new vocabulary over time through vocabulary activities strategically sequenced before or after content delivery. Cummins (2000) differentiated between conversational and academic language proficiency, indicating that ELLs require extensive teaching of subject-specific vocabulary (as examined in this pre- versus post-teaching study) to engage meaningfully with content taught in English due to their lack of academic English mastery. Specifically, Cummins emphasized building the advanced vocabulary and background knowledge essential for higher order thinking central to STEAM disciplines through deliberate vocabulary instruction strategically sequenced both prior to and after related content lessons as an essential distinction for ELLs in the STEAM disciplines.

In educational research, integrating ELLs into mainstream classrooms has gained increasing attention. Authors such as Gibbons (2002) have advocated for integrated instruction that interweaves language and content learning, asserting the importance of teaching essential STEAM vocabulary encountered in subject lessons (whether prior to or following content delivery) to allow deeper engagement and comprehension by ELLs. Gibbons also highlighted scaffolding academic language development in mainstream classrooms through vocabulary building exercises timed before and after the presentation of core lesson concepts. Larsen-Freeman (2001) promoted contextual and meaningful vocabulary learning, indicating that ELLs benefit from learning new terms like STEAM terminology in applicable situations such as real-world examples and textbook passages (presented both prior to and following related lectures, as explored in this study). She asserted that vocabulary taught in context, whether before or after content lessons, allows for deeper processing and retention as students relate terms to practical usages. Tarone (2005) offered views on contextual and meaningful vocabulary learning that are central to my study on the timing of STEAM vocabulary instruction. Tarone emphasized contextual vocabulary acquisition, stating that ELLs learn terminology like new STEAM words most successfully through usage in practical contexts — which could occur in vocabulary activities positioned either before or after content lessons per this study. Tarone also highlighted that enabling students to use new vocabulary in meaningful writing, dialogue, and reading comprehension promotes productive retention regardless of sequence.

My study is also based on Bailey's (2007) conceptualization of academic language proficiency and Pappamihiel's (2002) assertion that ELLs bring diverse educational backgrounds, cultures, and languages, which must be taken into account when selecting instructional strategies. Bruner (1996) and Mercer (1995) also support Vygotsky's idea that language plays a critical role in the learning of complex materials, such as STEAM vocabulary. Their work again reinforces the point that language gives students the tools to understand complex material and to then demonstrate that understanding. Through the integration of these varied theories and research, this study expects to contribute significantly to understanding how differing STEAM vocabulary instructional methods do or do not help the language needs of

ELLs when engaged in learning STEAM content. This has the potential to allow educators to select appropriate strategies more strategically to prepare ELLs to find academic success in science classrooms and beyond.

Overview of Methods and Data Collection

The research took place over a six-week period with two groups of ELL students. These groups were Group A, "Vocabulary First", and Group B, "Vocabulary Last". Each group received STEAM vocabulary instruction before a STEAM science lesson in one of two sequences; first, Group A was given STEAM vocabulary instruction at the start of each lesson then received a lecture and lab session or, lastly, Group B was given the lecture and lab session before the vocabulary instruction thus determining the sequencing of vocabulary instruction on the acquisition of learning STEAM vocabulary by ELL students.

There were multiple methods employed to fully understand the impact of the timing differences for vocabulary instruction on the learning outcomes of ELL students. A mixed-method assessment was used based upon one multiple-choice test (see Appendix A) and one vocabulary match quiz (see Appendix B), which allowed students' knowledge and understanding to be evaluated from varied perspectives, catering to students' different learning abilities and styles. A grading rubric (see Appendix C) was utilized to evaluate students' responses in oral exams against a standard, thereby ensuring consistency and fairness in scoring student performance. Exit tickets questions (See Appendix D) were used to solicit students' perceptions and attitudes towards the learning objectives, which captured the extent to which students obtained the stated content knowledge or accomplished the skill goals and the variability in their ability to perform, and provided insights into students' preferences, fears, and perceived effectiveness for each lesson sequence. This combination of quantitative and qualitative data added depth to the investigation’s findings, which provided a much richer picture of the instructional interventions’ impacts.

Demographics of Participants

The research was conducted using two ninth-grade science classrooms in an urban high school in the East Bay region of northern California – with a large percentage of ELL students. Twenty students – including 8 ELLs – comprised Class A, which received the pre-teaching vocabulary intervention. Sixteen students, including 8 ELLs, made up Class B, which received post-lesson vocabulary instruction. The diverse student body of the school includes 65.0% Latinx, 24.9% African American, 1.4% Asian, with an equal percentage of Caucasian students, contributed a rich cultural background. These students come from a range of backgrounds that inform their varying English proficiency levels and academic abilities. Table 1 presents an overview of the students’ characteristics, including gender, English proficiency, prior academic performance, when they entered schools in the United States, and which treatment group they were assigned to. To protect the privacy and confidentiality of the participants in this study, pseudonyms have been used in place of the students' real names throughout this paper.

The 16 students in this study represented a range of educational backgrounds and English proficiency levels. For example, Maria is a beginner English learner, who was an average student overall in her previous school. Diego, also a beginner, had average academic performance in his home country. Isabela, at early intermediate levels of English proficiency, had a strong background in science and excelled in science classes, indicating that she had a connection to the content and already possessed a vast knowledge and skills base. Miguel had high grades in his previous school, but his strength in science was not specified. Rodrigo and Jorge were both beginners, who had average grades before moving to the U.S. Sofia, with intermediate English proficiency, excelled academically in her previous school, specifically in science, indicating that she had a passion for and affinity to this subject area. Gabriela and Daniela, with early intermediate and advanced beginner English proficiency respectively, were also advanced in science in their home country, suggesting that they may have basic knowledge and skills in this subject area already, facilitating their ability to grasp new science concepts and vocabulary quickly. Alejandro and Perla at the beginner and advanced beginner levels had average academic performance before moving to the U.S. Mateo and Pablo, with intermediate English proficiency, had top scores on national exams in their previous country, illustrating a level of overall academic ability and content mastery that is very high, providing a foundation for their fast acquisition of English and learning of science. Karina and Rosa, both at the beginner level, had average grades in their home countries. Luis, with early intermediate English proficiency, struggled academically before coming to the U.S., suggesting potential gaps in his prior knowledge and skills that may impact his learning of new STEAM vocabulary and concepts.

It is important to note that the student background information and prior academic performance data presented in the table were gathered through a combination of personal conversations with students and a review of their cumulative school files. While every effort was made to ensure accuracy, it must be acknowledged that student records may not always provide a complete or fully up-to-date picture of their educational histories in their home countries. The information about their prior experiences and science backgrounds shared by students was anecdotal and inherently based on their own recall and perspective, which may be subject to potential bias and/or inconsistency.

Table 1

Demographics of the Participants

Student Pseudonym	Gender	English Proficiency Level	Prior Academic Performance	Entered US Schools	Group
Maria	Female	Beginner	Average	2022	A
Diego	Male	Beginner	Average	2023	B
Isabela	Female	Early Intermediate	Excelled in science	6 months ago	B
Miguel	Male	Beginner	Good grades	2023	A
Rodrigo	Male	Beginner	Average	2020	B
Sofia	Female	Intermediate	Excellent in science	2019	B
Jorge	Male	Beginner	Average	2021	B
Gabriela	Female	Intermediate	Excelled in science	2018	A
Alejandro	Male	Beginner	Average	2020	A
Perla	Female	Advanced Beginner	Average	2021	A
Mateo	Male	Intermediate	Top scores	2019	B
Karina	Female	Beginner	Average	6 months ago	B
Rosa	Female	Beginner	Average	2022	A
Luis	Male	Early Intermediate	Struggled academically	18 months ago	A
Daniela	Female	Advanced Beginner	Excelled academically	2020	B
Pablo	Male	Intermediate	Top scores	2022	B

In particular, the data presented about students' prior science knowledge and achievements in their home countries was heavily reliant on informal discussions held with students in which they were asked to describe their science experiences. While these conversations offer valuable illumination of the ELLs' own understanding of their scientific backgrounds, this information may not correspond to objective measures of the actual content knowledge or skill they may have. Therefore, the characterization of students as *excelled* in sciences from their previous countries and schools or as *average* in such schools should be understood as reflective of their general background and not objective assessments of their abilities.

Overall, this group of ELL students presents a wide range of scientific backgrounds and prior academic experiences. While some students, like Isabela, Sofia, Gabriela, and Daniela, have demonstrated strong performance in science, others, such as Maria, Diego, Rodrigo, and Jorge, have had more average academic records. Understanding these varied educational profiles is crucial for developing effective differentiation strategies and support systems to meet the diverse needs of ELL students in STEAM classrooms. The diversity of nationalities and migration patterns within this single classroom requires culturally responsive pedagogical techniques to support their transition.

Analysis of Multiple-Choice Test and Vocabulary Matching Quiz

To better understand the impact of the timing of vocabulary instruction on ELL student learning, I compared the results of the multiple choice test (Appendix A) and the vocabulary matching quiz (Appendix B) of the two treatment groups of students. On the multiple-choice test with 27 ecology questions, Group A had a mean score of 2.75 out of 4. Group B scored a 2.87 mean. On the 10-question vocabulary match quiz, the mean of Group A was 2.1 while Group B scored a mean of 2.3. Table 2 presents these results. Further analysis would be required to determine if these differences are statistically significant. Additional data on item analysis and individual question performance could provide more insights as well. Presentation of qualitative data from student interviews or surveys may also help contextualize the assessment results. This could provide a more comprehensive understanding of the factors influencing student performance.

Table 2

Summary of Results on Multiple Choice Test and Vocabulary Matching Quiz

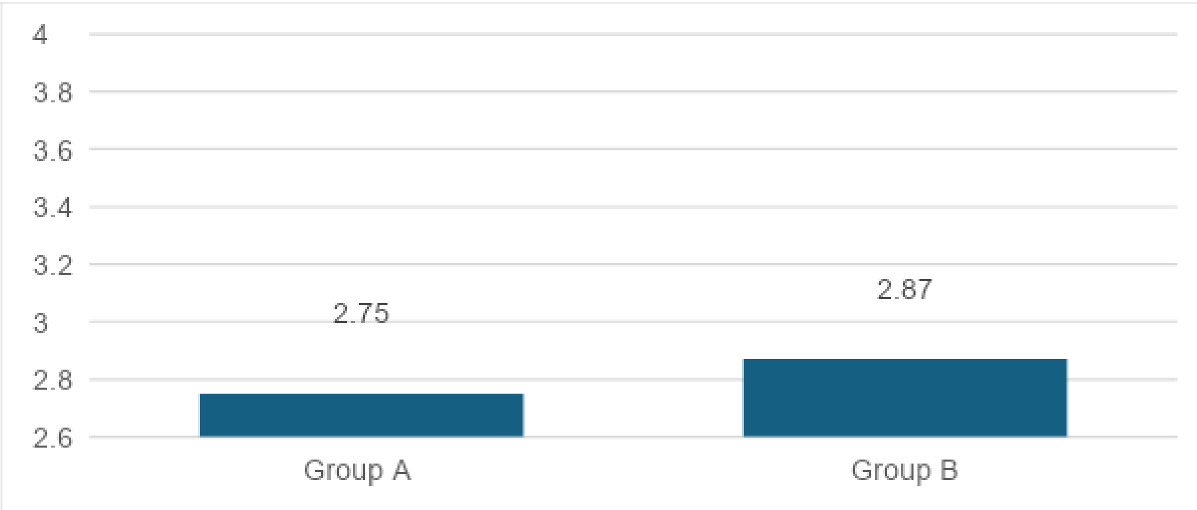
Group	Multiple Choice Test Mean	Vocabulary Matching Quiz Mean
Group A: Vocabulary First	2.75	2.1
Group B: Vocabulary Last	2.87	2.3

Multiple Choice Testing

The multiple choice test included 27-questions and focused on several ecology and environmental science subtopics, including biotic and abiotic factors, food webs, ecological succession, energy flow in ecosystems, producers, consumers, and decomposers, the importance of biodiversity, and factors impacting ecosystem stability. The test contained diagrams and graphs and required examinees to be able to interpret ecological data (e.g., to examine predator-prey relationships, energy distribution in food webs, and the impact environmental changes have on ecosystems). As shown in Figure 1, Group A (Vocabulary First) scored a mean of 2.75, which represents an average grade of C+ on the grading scale. The mean of Group B (Vocabulary Last) was slightly higher at 2.875, although this still translated to an average grade of C+ on the grading scale. Considering the minimal difference in mean scores that students achieved on the multiple-choice test, it is apparent that, regardless of whether vocabulary was presented before or after the STEAM content, both Groups A and B performed similarly.

Figure 1

Comparison of the Mean Scores of Group A and Group B on Multiple Choice Test



Note. The assessment scores were first categorized into traditional percentage grades and then converted into a numerical value based on a district grading scale to facilitate comparison: A (90-100%) as 4, B (80-89%) as 3, C (70-79%) as 2, D (60-69%) as 1, and F (59% and below) as 0.

Vocabulary Matching Quiz

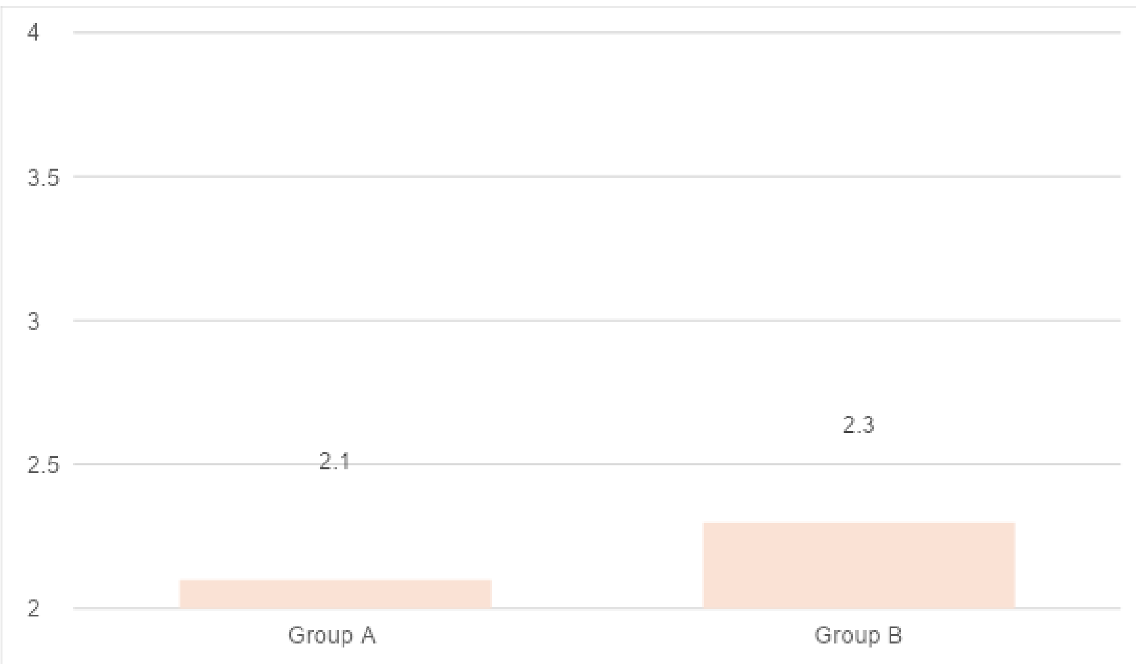
The vocabulary matching quiz asked students to match 10 ecological vocabulary terms with their correct definitions, quizzing their comprehension and retention of key concepts in ecology, such as *ecosystems*, *niches*, and the roles of different organisms within these systems. This portion of the assessment examined student knowledge of STEAM vocabulary, as well as their ability to apply this STEAM vocabulary in context. As shown in Figure 2, Group A (Vocabulary First) scored a mean of 2.1 on the vocabulary matching quiz, while Group B (Vocabulary Last)) posted a slightly higher mean score of 2.3.

Comparison Between the Multiple-Choice Test and Vocabulary Match Quiz

Figure 3 shows the difference in mean scores across assessments for ELLs. This allows a comparison of the ELLs' scores on a multiple-choice testing format with the same students' scores on a vocabulary match quiz. The mean scores of multiple choice test for Group A, which received vocabulary instruction first, was 2.75; and Groups A's corresponding mean for the vocabulary matching quiz was 2.1. Group B, the group that received vocabulary last, scored slightly higher, with 2.87 on the multiple choice and 2.3 on the vocabulary match quiz. This indicates a slight advantage for Group B in both testing formats, suggesting that the sequence of vocabulary introduction could have some impact on comprehension and retention even though the differences do not correspond to a higher letter grade.

Figure 2

Comparison of the Mean Scores of Group A and Group B on Vocabulary Matching Quiz

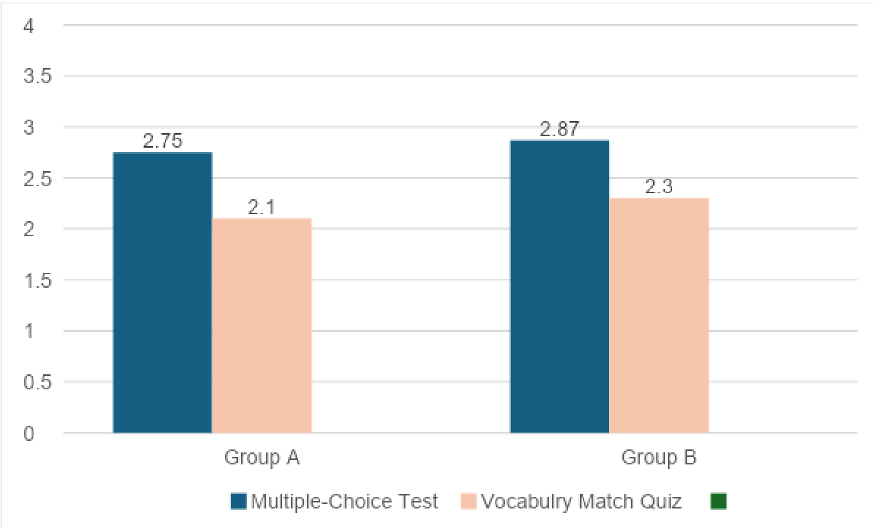


Note. A (90-100%) as 4, B (80-89%) as 3, C (70-79%) as 2, D (60-69%) as 1, and F (59% and below) as 0.

When comparing the multiple-choice and vocabulary match quizzes, both groups scored lower on average on the vocabulary match assessment. Group A's mean score was 0.65 points lower on the vocabulary quiz compared to multiple choice, while Group B's mean vocabulary score was 0.57 points lower than their mean multiple-choice score. This suggests students may have had more difficulty correctly matching specific ecology vocabulary terms to their definitions than answering conceptual multiple-choice questions covering broader ecological concepts.

Figure 3

Multiple-Choice Test vs. Vocabulary Matching Quiz: Mean Scores



Note. A (90-100%) as 4, B (80-89%) as 3, C (70-79%) as 2, D (60-69%) as 1, and F (59% and below) as 0.

The data show a consistent pattern of slightly higher scores for Group B regardless of testing format, indicating a minor benefit to introducing vocabulary after content instruction rather than before. However, the small differences in mean scores between groups also suggests that the sequence of vocabulary teaching did not have a measurable effect on student learning outcomes. Further analysis of statistical significance would need to be conducted to determine if the score differences were significant.

Analysis of Exit Tickets

The exit ticket activity (see Appendix D) served as an informal check on comprehension of student learning in both Group A and Group B. Students completed the exit ticket after they had completed the multiple choice test. Quantitative analysis for exit ticket scores allowed for comparisons of the general trends for the two groups. The students in Group A had a mean score of 2.5 correct responses out of 12 on the exit ticket. The scores ranged between a low of 1 to a high of 3, with a standard deviation of .756. Group B had a slightly higher mean of 2.875 out of a possible 12 on the exit ticket. The standard deviation was .641, with scores ranging from a low of 2 to a high of 4. Comparison of the means indicated a difference of .375, with students in Group B answering more items correctly. Examining the data distribution among individual students, Group B had more outliers than Group A, elevating the mean above their counterparts' mean exit ticket score.

Analysis of Individual Student Performance

Table 3 summarizes student outcomes across three forms of evaluation – a multiple choice exam, vocabulary matching quiz, and exit ticket. Five students in Group B, Isabela, Sofia, Mateo, Daniela, and Pablo, managed to demonstrate strong performance across the two ecology assessments, relative to the rest of the group, which may indicate an ability to effectively activate prior knowledge of science concepts to comprehend and analyze an environmental passage on a test. Compared to mean group scores of 2.87 on multiple choice and 2.3 on vocabulary matching, these students scored higher than average on both assessment, but especially on the vocabulary quiz. This may indicate the ability to not only comprehend the broader ecological principles tested in the multiple-choice format, but also to accurately recall definitions of science terms when making connections between concepts and STEAM vocabulary. The fact that there were five students in Group B who scored above the mean, as compared to one student in Group A, may help explain Group B's higher overall mean.

As individuals, students with strong backgrounds in science consistently outperformed many classmates. Isabela, Sofia, and Mateo, for example, all demonstrated a markedly strong understanding of the content in comparison to the rest of the ELLs. As it turns out, Isabela and Sofia may have science backgrounds stronger than any of their classmates.

Table 3

Summary of Individual Student Performance

Student Pseudonym	Group	Multiple Choice Test Average (out of 4)	Vocabulary Matching Quiz Average (out of 10)	Exit Ticket Score (out of 12)
Group A				
Maria	A	2	1.5	3
Miguel	A	2.5	2	4
Gabriela	**A**	**3**	**2.5**	**7**
Alejandro	A	2	1	2
Perla	A	2.1	1.9	3
Rosa	A	1.8	1.2	1
Luis	A	2	1.8	2
Group B				
Diego	B	2.6	2	5
Isabela	**B**	**3.2**	**3**	**7**
Rodrigo	B	2.7	1.8	6
Sofia	**B**	**3.5**	**3.5**	**9**
Jorge	B	2.3	1.6	3
Mateo	**B**	**3.8**	**3**	**10**
Karina	B	2.5	2	6
Daniela	**B**	**3.1**	**2.3**	**8**
Pablo	**B**	**3.7**	**2.8**	**11**

Isabela indicated that, until recently, she had lived in Mexico, and she had completed similar science courses, but in Spanish.

There are also exceptions to the common patterns in Group A. Gabriela also performed well, possibly because she applies what she knows from having been an honors student in her native country. Further research on the influence of prior schooling on language learning could reveal the predictive validity of many more of these background characteristics.

Summary

This study compares the effect of teaching vocabulary before versus teaching vocabulary after content instruction on STEAM subjects for ELL students in science classrooms. This chapter reported assessment findings from the two student groups who participated in this study Two groups of high school ELL students are compared. Group A received vocabulary instruction prior to content lessons, and Group B received vocabulary instruction after content lessons. Several quantitative assessments were used: a multiple-choice test (27 questions) on ecology, a vocabulary matching quiz (10 questions), an exit ticket (12 questions) completed after students completed the multiple choice test. Group A and Group B had respectively a 2.75 mean and a 2.87 mean on the multiple-choice test. Group A had a 2.1 mean, and Group B had a 2.3 mean on the vocabulary quiz. Overall, Group B scored 10% higher on the ecology exit ticket.

At the individual level, five Group B students scored above the average on these assessments, whereas only one student scored above the mean in Group A. When comparing Group A and Group B, minor differences were observed across the various assessments, with Group B scoring slightly higher on all measures. However, additional statistical analyses would need to be conducted with a larger sample to ascertain if these minor differences are significant. Further, qualitative data are needed to augment the quantitative results. The benefits of activating students' prior knowledge are suggested by looking at the individual student level data, as it provides contextual foundations for building new vocabulary comprehension. Identifying gaps in background knowledge also allows teachers to provide targeted scaffolding to support academic achievement. This aligns with Short's framework that tapping into prior academic knowledge provides tools for ELLs to acquire new vocabulary.

The next chapter will discuss these findings in relation to the literature reviewed in Chapter 2. Implications for teachers and for further research will also be discussed. The chapter will conclude with a reflection on the researcher's next steps as a school leader.

Chapter V

Discussion and Conclusions

The purpose of this research study was to examine the effects of pre-teaching versus post-teaching methods of vocabulary on ELLs' comprehension in science classrooms. The research focused on whether the sequence in vocabulary instruction for ELLs, eith during or after content lessons, was influenced ELLs' understanding and retention of STEAM vocabulary. The research concentrated around the most effective instructional approaches for ELLs to develop the intricate STEAM language in science classrooms.

The study was guided by the theoretical framework of Lev Vygotsky, Michael Halliday, and Howard Gardner. Vygotsky's sociocultural learning theory emphasizes the importance of language in cognitive development and the assumption that human learning is a spontaneous process that can only take place with the help of others who have more knowledge. Halliday's systemic functional linguistics considered the functional view of the language as a meaning-making code. Gardner's theory of multiple intelligences supports the idea that the people learn and create meaning in different ways. Each of these theories considers how language development and meaning making is interrelated, and how ELLs' learning models and styles impact their understanding and use of STEAM vocabulary.

Additionally, the research methodology was informed by the work of some leading scholars in this field of language acquisition and science education. Marzano and Beck came up with some of the most effective vocabulary instruction strategies, including reinforcing vocabulary, using pictures associated with words, and using words in a sentence to help learners understand the connecting words. According to Marzano, learners should have multiple exposures to the word. Marzano suggested that ELLs need to encounter new terms in different genres and contexts and also participate in activities that require them to use these terms in different ways. Marzano's ideas were relevant to the current study, where different approaches of pre- and post-teaching strategies were implemented to determine which procedures increase the ELLs vocabulary. Beck provided a system that categorizes vocabulary words into three categories, depending on their frequency and importance, and recommends that learners focus on the third section, academic words, or words necessary to understand and master STEAM vocabulary. This recommendation related well to the current study, which will focus on the STEAM subjects as participants in this study will need to learn vocabulary frequently used in the texts. Both Marzano and Beck similarly emphasized the need for explicit instruction of vocabulary and learning words using such ideas as focusing on their meaning and meaning in context.

With this in mind, Cummins' distinction between basic interpersonal communicative skills and cognitive academic language proficiency underscored the need for scaffolding academic language development for students. More specifically, Cummins stressed the importance of activating students' prior knowledge and leveraging their existing linguistic and cultural assets to help them acquire new academic language. The insight is directly relevant to the current study, which considered individual student factors such as prior education and language background may have shaped ELLs' responses to different vocabulary instruction approaches. Gibbons, Larsen-Freeman, and Tarone provided further context to the issue of contextual and meaningful vocabulary learning, with the emphasis on the integration of language and content instruction. Gibbons (2002) argued in favor of using scaffolding strategies in language and content instruction, claiming that teachers should provide support structures for students to access and make sense of challenging academic material. The concept of scaffolding is directly relevant to the current study's focus on pre- and post-teaching vocabulary approaches because both strategies involve providing targeted support to help students understand and use STEAM vocabulary. Larsen-Freeman argued for the importance of fostering communicative competence in language learning, noting that students should use the new language in authentic, meaningful interactions. The approach is directly relevant to the current study, which focuses on contextual and integrated vocabulary instruction because both pre- and post-teaching treatments seek to provide students with context-rich opportunities to engage with the vocabulary. Tarone presented the concept of learner variability in second language acquisition, suggesting that difference in learning styles and strategies as well as motivation can significantly affect the success of language learning. The concept is directly relevant to the current study, which included individual student differences such as prior education and language proficiency, because it points to the need to provide differentiated and personalized support for STEAM vocabulary acquisition.

Chapter IV has provided the results of the action research study, where two groups of ELL students underwent instructions on STEAM vocabulary either before STEAM content was taught (Group A) or after these content lessons (Group B) for six weeks. The impact was evaluated using multiple-choice questions, vocabulary match quizzes, and exit tickets. In general, the results demonstrated little difference between the groups in their STEAM vocabulary acquisition and retention, suggesting that when vocabulary is taught may not be an important factor vocabulary acquisition. Chapter V will present discuss these findings, their implications for practice, and the study's limitations.

Summary of Findings

To examine the effects of pre-teaching and post-teaching STEAM vocabulary strategies on ELLs' comprehension of science concepts, a two-group design was implemented. The subjects were 16 ninth-grade ELLs with different linguistic and cultural backgrounds. The subjects were equally divided into two groups, Group A, and Group B. While Group A received vocabulary instruction before content lessons, Group B received vocabulary instruction after content sessions. The study employed a mixed-methods design. It used multiple-choice tests, vocabulary match quizzes, oral exams, and exit tickets to evaluate ELLs' understanding and recall of STEAM terms.

Overall, the results of the analysis suggest that both Group A and Group B demonstrated improvement in their understanding of STEAM vocabulary throughout the six-week intervention period. However, Group B, which received post-lesson vocabulary learning, seemed to perform slightly better on all assessments than Group A. For example, on the multiple-choice graded test, the mean score was 2.75 for group A and 2.87 for Group B. Similarly, on the vocabulary match quiz, the mean score was 2.1 and 2.3, respectively. Both results indicated that although post-lesson vocabulary instruction might be slightly more effective, the overall difference was not significant enough to determine a preferred instructional timing.

A closer examination of individual student performance showed that existing knowledge and experience may have been important contributors to the variability within each of the two groups. ELLs who had strong academic backgrounds in their home countries had prior knowledge about relevant STEAM topics, and they consistently outperformed the rest of students in their group, despite the timing of exposure to vocabulary. For example, Isabela, who was successful in science courses in her home country, scored 3.2 on the multiple-choice test and 3.0 on the vocabulary quiz. Similarly, Mateo, who scored in top 5 % of national exams, managed to score 3.8 and 3.0 on respective tests, outscoring many students from Group B. For these students, having opportunities to connect English vocabulary with science content that they were already familiar with may have been an important factor, but further research must be conducted to learn more.

On the contrary, the pre-lesson vocabulary instruction did not make much impact on the scores of students who did not have strong backgrounds in STEAM content, such as Diego and Jorge in Group A. Diego, who had been an average student in his home country, received a score of 2.6 on the multiple-choice and a 2.0 on the vocabulary match quiz, with Jorge earning 2.3 and 1.6, respectively.

The benefits of activating students' prior knowledge during the introduction of new STEAM vocabulary were also highlighted by the study. As Short suggested (2011), connecting ELLs' preexisting knowledge of related concepts to new terminology enables easier incorporation of new information into existing cognitive schemas. This was especially the case for Gabriela, who had been an excellent science student prior to her relocation to the United States. Gabriela was in the Vocabulary First group. The early focus on vocabulary may have allowed her the opportunity to activate her prior knowledge because she scored 3.0 on the multiple-choice test and 2.5 on the vocabulary match quiz. These scores were higher than those achieved by many other students in this group.

After completing the multiple choice test and the matching quiz, I had one-on-one conversations with students to learn more about their understanding of the STEAM concepts and how the vocabulary instruction, whether before or after the science lessons, had influenced their learning. I discovered that these conversations provided opportunities for clarification and more elaborate explanations than the pen and paper assessments, therefore allowing ELLs to demonstrate their understanding of STEAM concepts more thoroughly. These data supported

Echevarria's finding that interactive and student-centered forms of lexically rich assessment are beneficial for academic language for ELLs. I noticed that, in my post-assessment conversations, the ELLs demonstrated much better understanding of scientific content compared to their performance on the multiple-choice and vocabulary matching assessments. On these pen-and-paper assessments, for example, both Luis and Rosa were unable to display their understanding of the four principles. In contrast, they were able to give much more detailed and correct responses during our oral discussions.

In conclusion, the research findings seem to indicate that ELLs could achieve slightly better outcomes in STEAM subjects following post-teaching vocabulary instruction. At the same time, it is evident that the timing of vocabulary introduction was not the primary factor affecting student performance. Certain individual characteristics, such as academic experience and prior knowledge, influenced ELLs' responses to vocabulary instruction. Additionally, the use of strategies that allow students to activate prior knowledge and seek clarification, such as oral discussions, proved to be effective in terms of ELLs' understanding and retention of STEAM terminology. Overall, it is possible for teachers to respond to the needs and experiences of their students by introducing strategic, student-responsive methods of teaching STEAM vocabulary to ensure the success of ELLs.

Interpretation of Findings

In sum, the findings of the present study indicate that post-teaching vocabulary instruction results in slightly improved performance of ELLs in STEAM subjects compared to the pre-teaching model. However, the sequence of vocabulary introduction to content instruction does not seem to be a determinative factor in students' success. The differences in mean scores of Group A and Group B are likely not significant and do not support the belief that either pre- or post-teaching vocabulary instruction is more effective in terms of ELLs' comprehension and retention of STEAM terminology. Rather, the study emphasizes that factors specific to the individual student, such as prior schooling and preexisting familiarity with STEAM concepts in the home language, may be key to shaping ELLs' responses to vocabulary instruction. Based on the outcomes of the participants in this study, it seems that students' educational experiences and preexisting background knowledge are essential drivers of ELLs' ability to learn and utilize new STEAM vocabulary.

These findings are consistent with both Vygotsky and Halliday's theoretical frameworks of learning language regarding complex subjects. The sociocultural theory of Vygotsky proposes that language is a critical component in the process of cognitive development that enables individuals to make sense of things and incorporate new concepts through social interaction. Similarly, Halliday's systemic functional linguistics theory states that meaning is formed and conveyed through language in connection to specific context. In the context of STEAM disciplines, reading proficiency in the students' first language and background knowledge in science both seemed connected to the students' success rates in science vocabulary retention.

Moreover, the study's results support Gardner's theory of multiple intelligences, demonstrating that students have varying ways of learning. The adopted assessment tools, including multiple choice, vocabulary match quizzes, and oral discussions, allowed ELLs to demonstrate their knowledge of STEAM concepts in ways that corresponded to their individual intelligences. In this regard, this study illustrates the importance of employing various assessment strategies to meet the diverse needs of ELLs' in STEAM education.

The results of the study also both align with and diverge from the work of several major authors in the fields of language acquisition and STEAM education. Gibbons and Larsen-

Freeman emphasize that for ELLs to succeed academically, language and content instruction must be integrated. On the one hand, the findings of this study confirm this outlook: STEAM vocabulary learning works best within contextually relevant content lessons as opposed to isolated vocabulary lists.

On the other hand, the research conducted by Marzano and Beck on strategic vocabulary instruction is also related to the findings of the study. The scholars contend that vocabulary instruction should include establishing multiple exposures to new words, providing students with practice and application, and supporting instruction with visual aids. In this regard, the precise moment of vocabulary introduction appears to be less critical. Based on the results, by utilizing such strategies, it is possible to improve ELLs' understanding and retention of STEAM vocabulary.

According to Echevarria and colleagues, it is critical to activate the ELL students' prior knowledge before STEAM vocabulary instruction. This approach is likely to particularly successful with students like Isabela, Sofia, Mateo, and other participants who have had strong academic experiences in their home countries. The data obtained from assessing students' prior knowledge can help teachers narrow their focus to aspects that require further exploration, thereby targeting the specific language and vocabulary needs of the identified ELL students.

The results of the research suggest that by activating prior knowledge, educators are able to scaffold meaning which aids ELLs in acquiring learned STEAM vocabulary more easily. A vivid illustration of this is the example of Gabriela, who, despite having the same vocabulary pre-taught before the test, was able to outperform her peers on both the multiple-choice test and vocabulary match quiz. Therefore, regardless of whether the words have been learnt from the context or vice versa, teachers can use the context of previously acquired vocabulary to give meaning to newly introduced STEAM vocabulary.

The recommendation from the aforementioned authors to use strategies that encourage students to apply new STEAM terminology along with their prior knowledge to enhance their understanding of the topic aligns with the study's results. Given that the research demonstrates the effectiveness of the strategy in improving ELL students' achievement in STEAM subjects, it is reasonable to conclude that activating prior knowledge to contextualize new terms may lead to a deeper understanding of the topic. The results of the study, along with Echevarria et al.'s research, support the conclusion that focusing on activating students' prior knowledge can enhance the effectiveness of STEAM vocabulary instruction. I believe this approach will help ELL students achieve greater academic success and provide them with the skills necessary to. Excel in STEAM fields.

Another variable, related to Cummins's research, that should be mentioned is the students' conversational versus academic proficiencies. Results of the study suggest that ELLs' pre-existing knowledge of the STEAM topics, which is largely dependent on their academic language proficiency, impacts their acquisition and utilization of the new vocabulary. Consequently, this finding emphasizes the importance of teachers scaffolding ELLs' academic language in addition to their oral proficiency to promote ELLs' understanding and retention of STEAM vocabulary. By connecting new information to students' backgrounds and addressing their academic language needs, teachers can better meet the diverse learning needs of all ELLs. The study's results underscore the significance of student variables, the alignment and consideration of language and content, appropriate vocabulary instruction, and targeted academic language development.

Implications for Teaching Practice

In order to secure the academic success of ELLs and make sure that they understand and memorize the STEAM vocabulary, teachers might need to take several different steps. One of those steps is the activation of prior knowledge prior to instruction, which might take the form of a task in which ELLs answer questions about what they know about the topics to discuss. A KWL chart, brainstorming, or another visual activity that will connect the new vocabulary to students' prior experience can also be employed. Teachers can help students create a context for new knowledge by placing their previous knowledge at the center. Ultimately, teachers need to help ELLs integrate new ideas into their existing knowledge.

Furthermore, based on the results of this action research study, I would recommend that teachers use various modes of assessments to allow for differences in learning styles and multiple intelligences. These assessments can range from verbal tests, written tests, to project-based tasks through which ELLs can demonstrate their knowledge to teachers and the peers. It is important to note that when teachers focus on the abilities and skills of each learner, including ELLs, they can create an equitable environment for all students. Many ELLs gain a better understanding of new vocabulary – and in generally remember new words better – by visualizing and connecting words with real-world objects. As a result, it is important for teachers to use visual support such as diagrams, charts, or real-world objects to associate a word more accurately with its actual meaning.

Determining when vocabulary instruction can make the most difference in ELLs' success is a challenging question to answer. However, I think that, based on these research results, teachers should provide both pre-teaching and post-teaching. First, teachers should pre-teach vocabulary about the STEAM topic to ELLs, so they have a framework for understanding this new topic. Second, teachers should engage in post-teaching by reintroducing new terminology in context so that ELLs can correctly use their new vocabulary.

In order to effectively address the needs of ELLs in STEAM, teachers should implement a range of strategies aimed at providing comprehensive support. First, teachers should differentiate instruction, meaning that ELLs should receive varying levels of support based on their English proficiency and level of education. Second, there is evidence that differentiated projects and the proximity of proficient ELLs to English-speaking students increased the effectiveness of the intervention. In addition, teachers working with ELLs in STEAM might seek out professional development focusing on the theory of language acquisition and instruction, as well as on effective methods of teaching to ELLs. Finally, teachers can monitor ELLs' progress daily and have one-on-one conversations to learn if the students require additional help. In addition, classroom culture can support ELLs in their STEAM vocabulary learning. Specifically, teachers can work to integrate ELLs' home language and culture into daily lessons. This may help students feel more connected with the materials and more motivated to learn. In summary, effective support for ELLs in STEAM language acquisition requires differentiated instruction, professional development, and culturally relevant practices.

Limitations and Suggestions for Future Research

Although this study provides important information on the impact of the timing of instruction on the comprehension of STEAM vocabulary by ELLs, it is crucial to acknowledge its limitations and suggest areas for future research. Because this study included only 16 ELLs from a particular high school, the findings are not generalizable. As a result, future studies should include larger and more representative and diverse samples of ELLs from various schools and grade levels to ensure that the findings can have high external validity, as recommended by researchers such as Okhee Lee and Cory Buxton (2010). In their work, they emphasized the importance of using larger, more representative samples of ELLs from diverse educational settings to enhance the generalizability of findings related to effective STEAM vocabulary instruction. Lee and Buxton's research also highlights the need for collaborative interdisciplinary research involving STEAM educators, language specialists, and researchers. Only through collaboration can innovative approaches that address the unique language and learning challenges of ELLs in STEAM classrooms be developed and tested.

Another limitation of the study is related to the vocabulary and concepts covered. The study did not consider the entire range of STEAM vocabulary and ideas. Caution should be exercised when applying these findings to the instruction of more advanced STEAM concepts and terminology. Overall, more research is needed to understand how the timing of vocabulary instruction may affect ELLs' comprehension of various STEAM topics and skills, and further investigation of this topic is warranted. Janzen (2008) emphasized the value of exploring the unique language demands of different STEAM disciplines and how these demands may support or hinder ELLs' academic success. She suggested that future research should focus on the impact of various instructional strategies, such as activating prior knowledge and providing explicit vocabulary instruction, on ELLs' comprehension and acquisition of discipline-specific language. Janzen also highlighted the importance of longitudinal research to explore the long-term effects of these approaches on ELLs' language development and academic achievement in STEAM.

In order to obtain more thorough insights into the long-term impacts of the timing of vocabulary instruction on ELLs in the context of STEAM learning, longitudinal studies should be conducted. Specifically, by observing how teachers select their target audience and analyzing data collected over several semesters, researchers could determine offer more insights in how and when teaching vocabulary is more effective. In particular, longitudinal studies might enable researchers to determine the extent to which vocabulary learned in one course influences learners' performance in subsequent courses and their future acquisition and application of STEAM vocabulary in professional settings. Also, this approach will help track the cumulative impact of specific vocabulary instruction methods on ELLs' success in their further academic pursuits and potential careers in STEAM fields.

Slama et al. (2017) recently presented a case study demonstrating the value of longitudinal research in tracking ELLs' development and academic outcomes over time, including their participation in STEAM education. Slama and colleagues' findings indicate that longitudinal research can provide a deeper understanding of the multiple and complex predictors that likely influence ELLs' access to and progress in STEAM programs. By tracking ELLs' trajectories over an extended period, researchers can gain substantial understanding of the impact that various strategies and interventions have on their language proficiency and academic success in science classrooms.

In addition to conducting longer studies, future research should include qualitative methods in order to capture ELLs' perceptions, experiences, and attitudes with regard to STEAM subjects. In-depth interviews, observational data, and focus groups could provide greater insight into the challenges and opportunities that ELLs encounter as they learn the STEAM vocabulary. Furthermore, this type of research can shed light on the preferences that ELLs might have regarding instructional and assessment methods. In addition, research using a qualitative approach may provide a deeper understanding about how the school/home/community relationship may influence ELLs' experiences in learning STEAM subjects.

In addition, there is a need for future studies to investigate the role of individual learner factors, such as motivation, self-efficacy, and learning styles, in moderating the effects of vocabulary instruction timing on ELLs' STEAM comprehension. By analyzing the interaction among these factors and different instructional approaches, researchers will be able to develop more adaptive and personalized strategies for supporting ELLs in acquiring STEAM language. As Cummins (2001) and Chamot (2009) have pointed out, when developing language instruction for ELLs, it is essential to consider individual learner factors.

Finally, research is needed on the intersectionality of language, race, ethnicity, and gender in shaping ELLs' access and opportunities for success in the STEAM education. As pointed out by researchers as Solórzano and Yosso (2002) and Gándara and Contreras (2009), ELLs' experiences and opportunities in STEAM classrooms are shaped by complex power relations and systemic inequalities. In summary, the current action research study may have made a contribution to our understanding the impact of vocabulary instruction's timing on ELLs' STEAM comprehension. However, research is also needed to address the limitations and shortcomings of the current study. By conducting further large-scale and long-term, longitudinal, and qualitative studies, focusing on individual learner characteristics, investigating the impact of teacher professional development, fostering interdisciplinary teaching, employing advanced technology, gaining family and community support, and addressing the issues of equity and intersectionality, researchers will better understand how to support ELLs in STEAM subjects.

Plan for Future Action

This research has revealed a number of factors that are likely to help me improve my instructional practice and help ELLs to acquire STEAM vocabulary more effectively. I am now aware that activating prior knowledge is an essential strategy regardless of the quality of students' experiences in their home countries.

As I transition from a teaching role to an administrative position, I intend to undertake the following steps to translate the research findings on the effects of instructional timing on ELLs' STEM vocabulary learning into actionable goals. First, I will present the findings of the research to the teachers and administrators working at my school and the district level. By presenting the study's arguments and proposed accommodations, I aim to raise awareness of the challenges ELLs face in learning STEAM vocabulary. In addition, I will use the studies conducted by Pauline Gibbons (2002) and emphasize that science instruction should build upon ELLs' prior knowledge. These strategies are expected to encourage teachers and administrators to adopt appropriate scaffolding techniques to support ELLs' learning.

After the completion of this project, I will work with teachers and ESL specialists to create and introduce a pilot project for differentiated vocabulary instruction. Marzano's research indicates that direct instruction of new and complex vocabulary, along with ensuring that new words are revisited and applied, is associated with improved learning outcomes. Similarly, Beck affirms that for students to remember learned words, they need to engage with them meaningfully and repeatedly. The project will involve using vocabulary journals and creating a shared repository of differentiated lesson plans, activities, and assessments designed to enhance the instruction and exposure to new words based on the needs in STEAM subjects. To enhance the effectiveness of the presented programs, I will encourage the collaboration between STEAM instructors and language experts, both in the school that I work in and across the district. Drawing from the research of Larsen-Freeman and Tarone, who emphasize the simultaneous teaching of language skills and content, I will advocate for the creation of opportunities for collaborative planning, co-teaching, and resource sharing to support ELLs. Having accessed the experience of such professionals as Pauline Gibbons, Fred Geese, and Roy Lyster, I will work to integrate coordinated support and create a more robust educational environment for ELLs throughout the district.

Apart from these school- and district-level initiatives, I intend to continue my research and advocacy work concerning effective practices for ELL teaching in STEAM subjects. Following the example of such scholars as Stephen Krashen, Ofelia García, Wayne Thomas, and Virginia Collier, who put a strong emphasis on the significance of bilingual education and need for taking the students' home languages into account in teaching them, I will have to look for opportunities for carrying out more research on the subject and distributing the resulting information through publishing, conference presentations and community events.

Ultimately, my future plans are grounded in my commitment to educational equity. By utilizing the information gathered from scholars and researchers, and by collaborating with educators, families, and community stakeholders, I aim to work toward creating more inclusive and responsive learning environments that recognize and celebrate the rich assets and experiences that ELLs bring to the STEAM subjects. By remaining persistent, advocating for change, and being open to feedback and learning, we can transform the landscape of education and ensure that no ELL is left behind on the path to success in the world of science and beyond.

Summary

Three conclusions can be drawn from the findings of this research, which have significant implications for educators and administrators teaching STEAM subjects in ELLs' classrooms. These three conclusions offer clear recommendations or guidance for educators seeking to enhance the academic performance of ELL students in science classrooms.

First, the study provides evidence that it may not make a significant difference to learners whether vocabulary is introduced before the main content lesson, or afterward. The fact that the differences in mean scores are minor suggests that the timing of vocabulary instruction may not be the critical factor in determining ELLs' performance in STEAM learning. This finding contradicts the assumption that front-loading vocabulary is always the best approach and suggests that educators should focus on other aspects, such as the quality and relevance of the instruction, in designing lessons for their ELLs.

Second, the study highlights the significance of activating prior knowledge in promoting ELLs vocabulary development. This strategy is crucial for enhancing ELLs' vocabulary achievement. Educators should implement activities that help students recall their prior understanding of related concepts. This would enable educators to create a meaningful context for new understanding and simplify the process of incorporating new information into already existing cognitive schemas. This method would be particularly beneficial for ELLs who have a strong educational background from their home countries. This is because students can use their prior understanding to make links and develop their STEAM vocabulary understanding further. The research highlights the importance of recognizing and leveraging students' diverse linguistic, cultural, and academic assets.

Third, I can employ the knowledge I have obtained from this study to facilitate changes in school-wide policies and practices as I move from being a classroom teacher to an administrator. I can share the study's results and implications with colleagues and district officials to encourage the implementation of strategies that better support ELLs' acquisition of STEAM vocabulary and ultimately improve their outcomes in science. Moreover, the study's results can offer valuable guidance for school and district leaders in creating professional development opportunities for teachers. The opportunities might include the study of the theories of language acquisition, proper use of sheltered instruction techniques, and requirements of culturally responsive teaching.

To sum up, this research offers further insight into the significance of a holistic, student-centered approach to STEAM vocabulary instruction for ELLs. In my future leadership roles, I will apply the knowledge gained from this study to foster an equitable learning environment and ensure that students experience inclusivity, respect for their prior experiences, and recognition of their unique strengths. By emphasizing the activation of students' prior knowledge, supporting oral language development, and providing differentiated instruction as essential strategies for promoting target vocabulary acquisition among ELLs, I aim to help students view themselves as capable and intelligent members of STEAM fields.

Having gone through the process of learning English as my second language, I fully realize the opportunities and difficulties that ELL students encounter daily. As I continue my research and apply this knowledge in my future role as an administrator, I will be better equipped to support students in similar programs, helping them overcome their challenges and achieve their goals in STEAM education. Overall, I believe that my experiences and the insights gained from this study can contribute to the broader goal of creating better opportunities for all students. Specifically, I will be able to join others who are working to promote equity and diversity in schools, striving to help every student, regardless of background, reach their full potential.

To conclude, this study has made a humble contribution to understanding the multifaceted influences on ELLs' STEAM vocabulary acquisition and provided practical recommendations for instruction and professional development. As I enter the next chapter of my career as an educational leader, I look forward to continuing this journey of discovery and advocacy with my colleagues, students, and community partners, and fostering a brighter, more inclusive future. Together we can build a better educational system that values every student's potential and helps them make substantial contributions to the STEAM world and beyond.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

Anstrom, K., DiCerbo, P., Butler, F., Katz, A., Millet, J., & Rivera, C. (2010). *A review of the literature on academic English: Implications for K-12 English language learners*. The George Washington University Center for Equity and Excellence in Education.

August, D., Branum-Martin, L., Cárdenas-Hagan, E., Francis, D. J., Powell, J., Moore, S., & Haynes, E. F. (2014). Helping ELLs meet the common core state standards for literacy in science: The impact of an instructional intervention focused on academic language. *Journal of Research on Educational Effectiveness*, *7*(1), 54-82.

August, D., & Shanahan, T. (2006). *Developing literacy in second-language learners*. Lawrence Erlbaum Associates

Bailey, A. L. (2007). *The language demands of school: Putting academic English to the test*. Yale University Press.

Baram-Tsabari, A., & Osborne, J. (2015). Bridging science education and science communication research. *Journal of Research in Science Teaching, 52*(2), 135-144. https://doi.org/10.1002/tea.21294

Bravo, M. A., Hiebert, E. H., & Pearson, P. D. (2007). Tapping the linguistic resources of Spanish/English bilinguals: The role of cognates in science. In R.K. Wagner, A.E. Muse, & K.R. Tannenbaum (Eds.), *Vocabulary acquisition: Implications for reading comprehension* (pp. 140-156). Guilford Press.

Bruner, J. S. (1996). *The culture of education*. Harvard University Press.

Buxton, C. A., & Lee, O. (2014). *English language learners in science education*. In N. G. California Department of Education. (2016). *California English language development test reports:* https://celdt.cde.ca.gov/reports.asp

California Department of Education, 2014 & 2107, *English Language Development Standards for California Public Schools: Kindergarten through Grade Twelve*. Retrieved from https://www.cde.ca.gov/sp/el/er/documents/eldstndspublication14.pdf

California Department of Education. (2016). *California English language development test information guide:* http://www.cde.ca.gov/ta/tg/el/resources.asp

California Department of Education. (2017). *2016-17 Four-year adjusted cohort graduation rate:* https://dq.cde.ca.gov/dataquest

California Department of Education. (2018). *Facts about English learners in California CalEdFacts:* https://www.cde.ca.gov/ds/sd/cb/cefelfacts.asp

California Department of Education. (2013). *The California common core state standards: English language arts and literacy in history/social studies, science, and technical subjects.*

Collier,V. P. (1987).Age and rate of acquisition of language for academic purposes. *TESOL Quarterly, 21*(4), 677–741.

Collier, V.P., & Thomas, W.P. (1989). How quickly can immigrants become proficient in school English? *Journal of Educational Issues of Language Minority Students, 5*, 26-38.

Cummins, J. (2000). *Language, power, and pedagogy: Bilingual children in the crossfire.* Multilingual Matters.

Curcio, C. C., & Roberts, J. (2003). Evaluation of a school district's secondary counseling program. *Professional School Counseling*, *6*(4), 296-303. https://www.jstor.org/stable/42732443

De Jong, E. J. (2011). *Foundations for multilingualism in education: From principles to practice*. Caslon Publishing.

Echevarria, J., Vogt, M.E., & Short, D. (2008). *Making content comprehensible for English learners: The SIOP model.* Pearson Education.

Hakuta, K., Butler, Y.G., & Witt, D. (2000, January). *How long does it take English language learners to develop oral proficiency and academic proficiency in English?* University of California Linguistic Minority Research Institute.

Hammer, C. S., Hoff, E., Uchikoshi, Y., Gillanders, C., Castro, D. C., & Sandilos, L. E. (2014). The language and literacy development of young dual language learners: A critical review. *Early Childhood Research Quarterly*, *29*(4), 715-733.

Halliday, M.A.K. (1975). *Learning how to mean.* Edward Arnold

Halliday, M.A.K. (2002). *Linguistic studies of text and discourse* (Webster, J., Ed.). Continuum International Publishing.

Halliday M.A.K., (2006). *The language of science* (Webster, J. Ed.). Continuum International Publishing.

Halliday, M.A.K. (1978). *Language as social semiotic: The social interpretation of language and meaning*. Edward Arnold.

Halliday, M.A.K. (1973) *Explorations in the functions of language.* Edward Arnold.

Halliday, M.A.K. (2006). *Computational and quantitative studies* (Webster, J, Ed.). Continuum International Publishing.

Hirsh, David, (2012) *Current perspectives in second language vocabulary research,* AG, International Academic Publishers.

Huerta, M., Irby, B. J., Lara-Alecio, R., & Tong, F. (2015). Relationship Between language and concept science notebook scores of English language learners and/or economically disadvantaged students. *International Journal of Science and Mathematics Education*, *14*(S2), 269-285.

Fenner, D.S., & Snyder, S. (2017). *Unlocking English learners' potential strategies for making content accessible.* Corwin.

Krashen, Stephen, (1982). *Principles and practice in second language acquisition*. Oxford University Press.

Lederman & S.K. Abell (Eds.), *Handbook of research on science education* (Vol. 2). Routledge.

Lee, O., Quinn, H., & Valdés, G. (2013). Science and language for English language learners in relation to Next Generation Science Standards and with implications for Common Core State Standards for English language arts and mathematics. *Educational Researcher*, *42*(4), 223-233.

Lee, S. H., & Muncie, J. (2006). From receptive to productive: Improving EFL learners' use of vocabulary in a post-reading composition task. *TESOL Quarterly*, *40*(2), 295-320.

Marincola, E. (2006). Why is public science education important? *Journal of Translational Medicine*, *4*, 7. http://doi.org/10.1186/1479-5876-4-7

Mariëlle J., Prevoo, L., Malda, M., Mesman, J., & van IJzendoorn, M. H.. (2016). Within- and cross-language relations between oral language proficiency and school outcomes in bilingual children with an immigrant background. *Review of Educational Research*, *86* (1), 237 – 276.

McNeill, K., Lizotte, D., Krajcik, J., & Marx, R. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *Journal of the Learning Sciences*, *15(*2), 153-191. doi: 10.1207/s15327809jls1502_1

Mercer, N. (1995). *The guided construction of knowledge: Talk amongst teachers and learners.* Multilingual Matters.

Mercer, N., Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: Ways of helping children to use language to learn science. *British Educational Research Journal, 30*(3), 359-377.

National Education Association. (2017). Research Talking Points on English Language Learners. Retrieved from http://www.nea.org/home/13598.htm

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science, 328*(5977), 463-466.

Pappamihiel, N. E. (2002). English as a second language students and English language anxiety: Issues in the mainstream classroom. *Research in the Teaching of English, 36*(3), 327-355.

Powers, A., & C. Stanfield. 2009. Developing science literacy for English language learners. *AccEELerate 2*(1), 11-12.

Proctor, C. P., August, D., Carlo, M. S., & Snow, C. (2012). The intriguing role of Spanish language vocabulary knowledge in predicting English reading comprehension. *Journal of Educational Psychology*, *104*(1), 8-29. https://doi.org/10.1037/a0026024

Rueda, R., & Garcia, E. (2001). Teacher beliefs and practices on Latino students: Sociocultural influences, contexts, and outcomes. In J. Banks & C. Banks (Eds.), *Handbook of Research on Multicultural Education (*pp. 335-363). Jossey-Bass.

Short, D., & Fitzsimmons, S. (2007). *Double the work: Challenges and solutions to acquiring language and academic literacy for adolescent English language learners – A report Carnegie Corporation*. Alliance for Excellent Education.

Snyder, E., Witmer, S.E., & Schmitt, H. (2017) English language learners and reading instruction: A review of the literature, *Preventing School Failure: Alternative Education for Children and Youth, 61*(2), 136-145,

Thompson, G. (2014). *Introducing functional grammar* (3rd ed.). Routledge.

Townsend, D., Brock, C., & Morrison, J. (2018). Engaging in vocabulary learning in science: The promise of multimodal instruction. *International Journal of Science Education, 40,* 328 – 347.

Townsend, D., Filippini, A., Collins, P., & Biancarosa, G. (2012). Evidence for the importance of academic word knowledge for the academic achievement of diverse middle school students. *The Elementary School Journal, 112*(3), 497-518.

Vygotsky, Lev. (1978) *Mind in society: The development of higher psychological processes*. Harvard University Press.

Vygotsky, Lev. (1986). *Thought and language*. Rev.ed., A. Kozulin, Ed.). MIT Press.

Welsh, A., Shaw, A., & Fox, J. (2017). Research and teaching: The pairing of a science communications and a language course to enrich first-year English language learners writing and argumentation skills. *Journal of College Science Teaching.* 46(3), 61-66.

Wessels, S. (2013). Science as a second language. *Science and Children*, 51(1), 24-28.

Wood, D. J., Bruner, J. S. and Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychiatry and Psychology*, 17(2), 89-10.

Zwiers, J. (2008). *Building academic language: Essential practices for content classrooms.* International Reading Association.

Appendices

Appendix A

Ecology – Multiple Choice Test

1. One biotic factor that affects consumers in an ocean ecosystem is

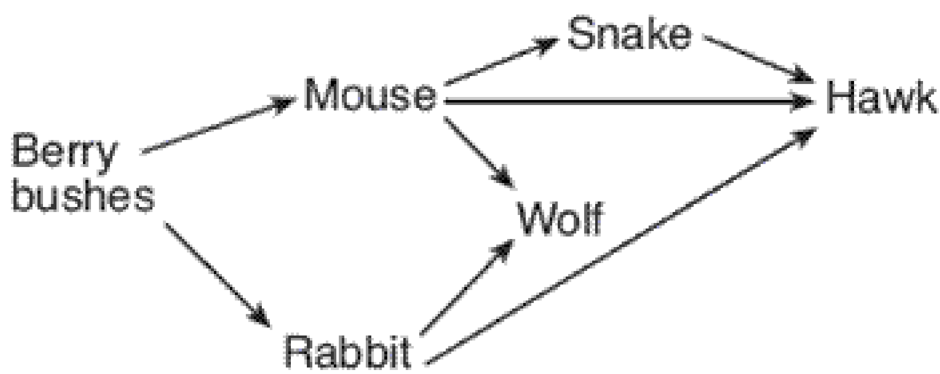
   A. number of autotrophs

   B. temperature variation

   C. salt content

   D. pH of water

2. A food web is represented in the diagram below.



Which population in this food web would most likely be *negatively* affected by an increase in the mouse population?

   A. snake

   B. rabbit

   C. wolf

   D. hawk

3. Some bloodsucking insects insert their mouthparts directly into a blood vessel and withdraw blood. Other bloodsucking insects have mouthparts that cut through the skin and blood vessels and produce a small pool of blood from which they feed. Both mouthpart types are specialized for

A. autotrophic nutrition

B. heterotrophic nutrition

C. regulation

D. excretion

4. Decomposers are important in the environment because they

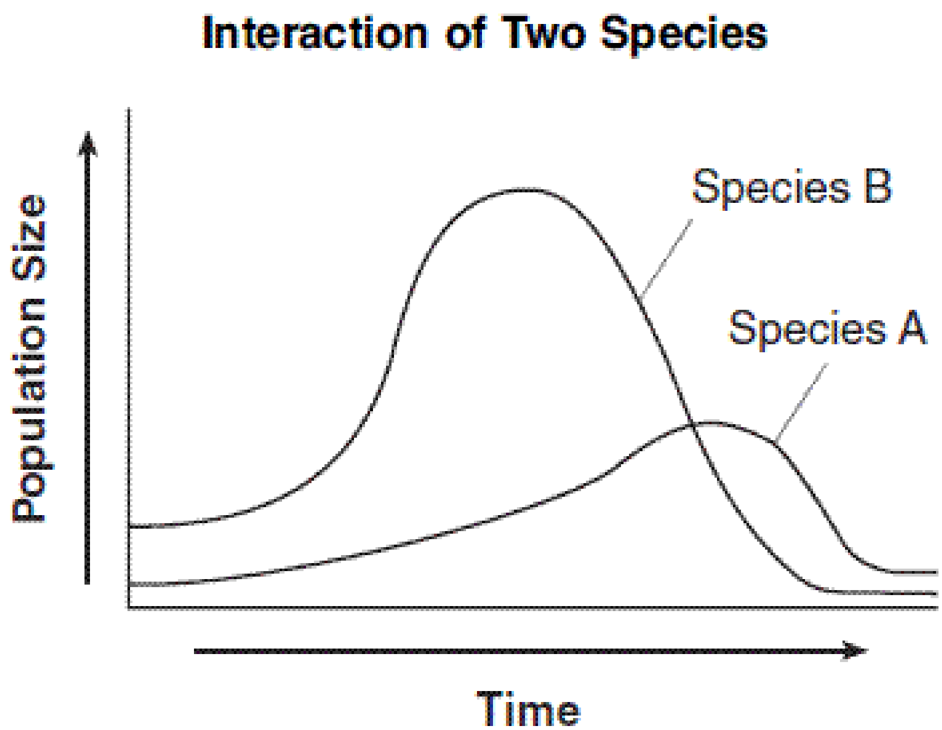
A. convert large molecules into simpler molecules that can then be recycled

B. release heat from large molecules so that the heat can be recycled through the ecosystem

C. can take in carbon dioxide and convert it into oxygen

D. convert molecules of dead organisms into permanent biotic parts of an ecosystem

The graph below shows changes in the populations of two species that interact only with each other over a period of time.



5. Which statement best describes these two species?

A. Species *A* is a producer and species *B* is its consumer.

B. Species *A* is a host and species *B* is its parasite.

C. Species *A* is a predator and species *B* is its prey.

D. Species *A* is a scavenger and species *B* is its decomposer.

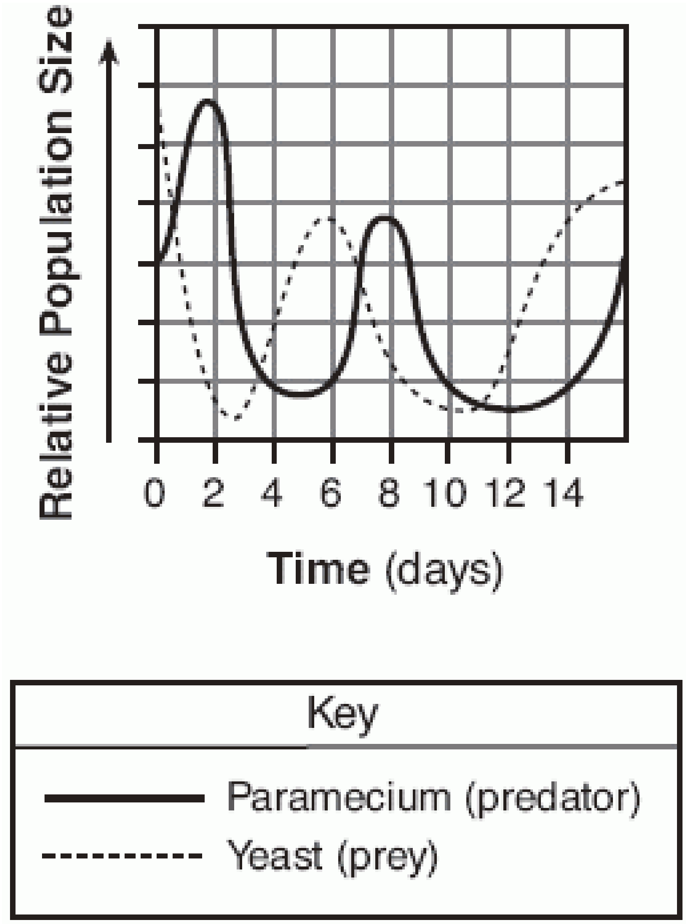
6. A new island formed by volcanic action may eventually become populated with biotic communities as a result of

A. a decrease in the amount of organic material present

B. decreased levels of carbon dioxide in the area

C. the lack of abiotic factors in the area

D. the process of ecological succession



7. What is the most probable reason for the increasing predator population from day 5 to day 7?

A. an increasing food supply from day 5 to day 6

B. a predator population equal in size to the prey population from day 5 to day 6

C. the decreasing prey population from day 1 to day 2

D. the extinction of the yeast on day 3

8. Which statement best describes the flow of energy and the movement of chemical compounds in an ecosystem?

A. Energy flows into living organisms and remains there, while chemical compounds are transferred from organism to organism.

B. Chemical compounds flow in one direction in a food chain and energy is produced.

C. Energy is transferred from organism to organism in a food chain and chemical compounds are recycled.

D. Energy flows out of living organisms and is lost, while chemical compounds remain permanently inside organisms.

9. One biotic factor that limits the carrying capacity of any habitat is the

A. availability of water

B. level of atmospheric oxygen

C. activity of decomposers

D. amount of soil erosion

10. Abiotic factors that characterize a forest ecosystem include

A. light and biodiversity

B. temperature and amount of available water

C. types of producers and decomposers

D. pH and number of heterotrophs

11. A particular species of unicellular organism inhabits the intestines of termites, where the unicellular organisms are protected from predators. Wood that is ingested by the termites is digested by the unicellular organisms, forming food for the termites. The relationship between these two species can be described as

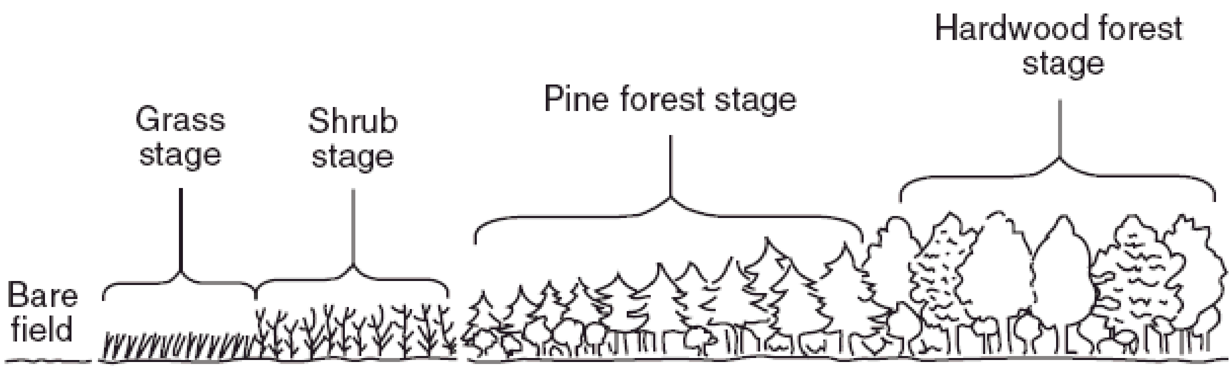
A. harmful to both species

B. parasite/host

C. beneficial to both species

D. predator/prey

12. The diagram below represents a biological process taking place in an area of New York State unaffected by natural disasters.



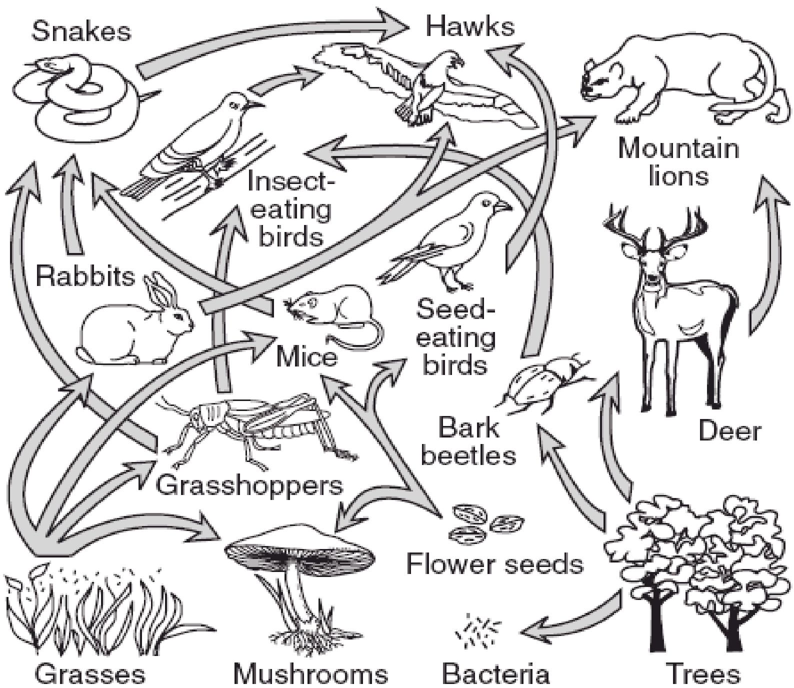
Which statement correctly describes a stage in this process?

A. The grass stage is the most stable stage and exists for thousands of years.

B. The shrub stage modifies the ecosystem, making it more suitable for the pine forest.

C. The pine forest stage has no biodiversity and the least competition.

D. The hardwood forest stage will be replaced by a pine forest.



13. Which organisms are correctly paired with their nutritional roles shown above?

A. hawk—decomposer; insect-eating bird—parasite

B. mouse—autotroph; flower seed—heterotroph

C. mountain lion—predator; bark beetle—herbivore

D. grasshopper—carnivore; grass—autotroph

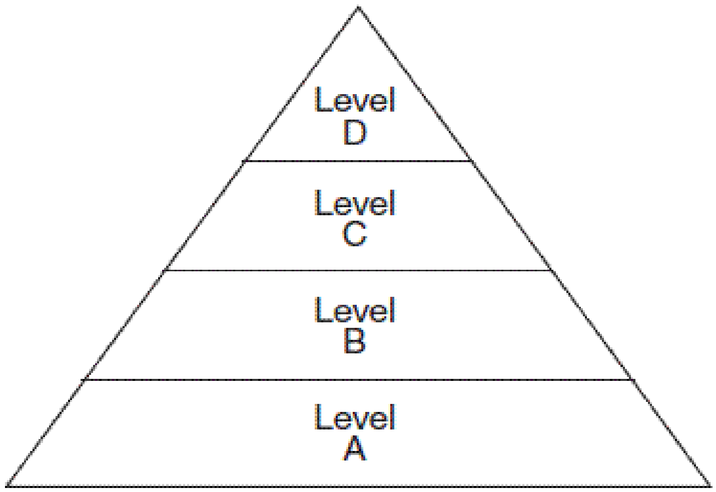
14. An established ecosystem may remain stable over hundreds of years because

A. species interdependence is absent

B. there is a lack of variety in the species

C. no competition exists between the species

D. there are natural checks on species



15. The energy for use by organisms in level A originally comes from

A. producers

B. the Sun

C. level B

D. level D

16. The reason that organisms cannot produce populations of unlimited size is that

A. the resources of Earth are finite

B. there is no carrying capacity on Earth

C. species rarely compete with one another

D. interactions between organisms are unchanging

17. What will most likely occur if two different plant species compete for the same requirements in an ecosystem?

A. They will usually develop different requirements.

B. One species may adapt to a different environments

C. One species may be eliminated from that ecosystem.

D. They will alter the environment so that they can both survive in that ecosystem.

18. Abiotic factors that could affect the stability of an ecosystem could include

A. hurricanes, packs of wolves, and temperature

B. blizzards, heat waves, and swarms of grasshoppers

C. droughts, floods, and heat waves

D. species of fish, number of decomposers, and supply of alga

19. The size of a mouse population in a natural ecosystem tends to remain relatively constant due to

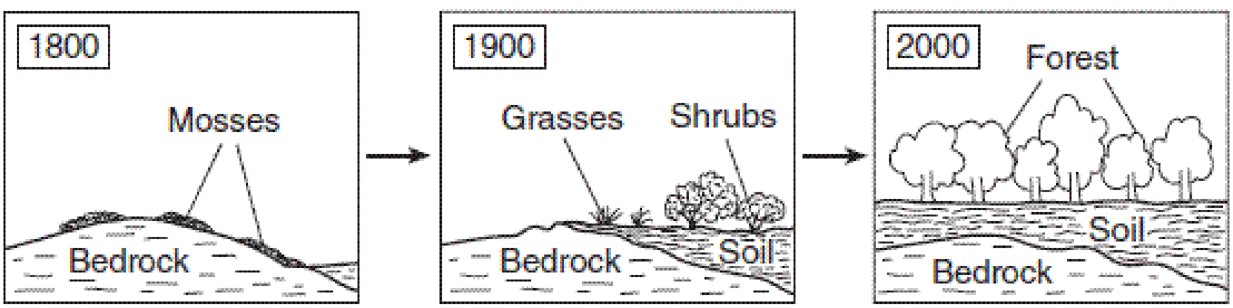
A. the carrying capacity of the environment

B. the lack of natural predators

C. cycling of energy

D. increased numbers of decomposers

20. The diagram below represents a process that occurs in nature.



This diagram can be used to illustrate the

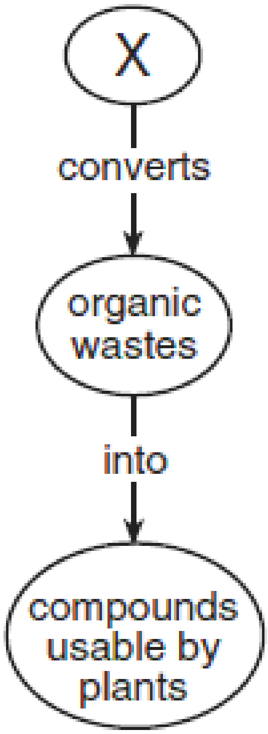
A. effects of reduced competition between different types of plant life

B. effect of human intervention on a stable ecosystem

C. ecological succession from bare rock to stable ecosystem

D. evolution of mosses to trees over 200 years

21. The process illustrated in the sequence below occurs constantly in the biosphere.



Which type of organism is most likely represented by *X*?

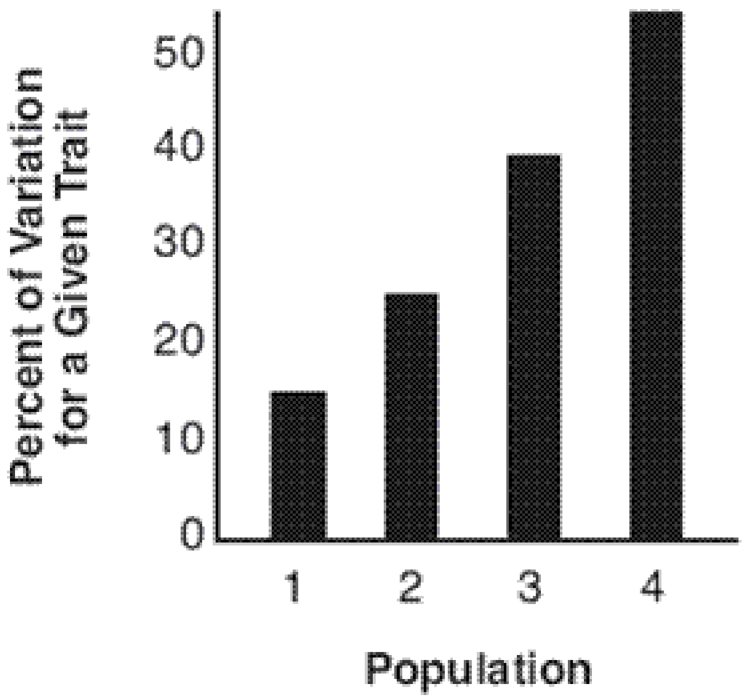
A. decomposer C. herbivore

B. producer D. carnivore

22. Which component of a stable ecosystem can not be recycled?

A. oxygen B. water C. energy D. nitrogen

23. The graph below shows the percent of variation for a given trait in four different populations of the same species. The populations inhabit similar environments.



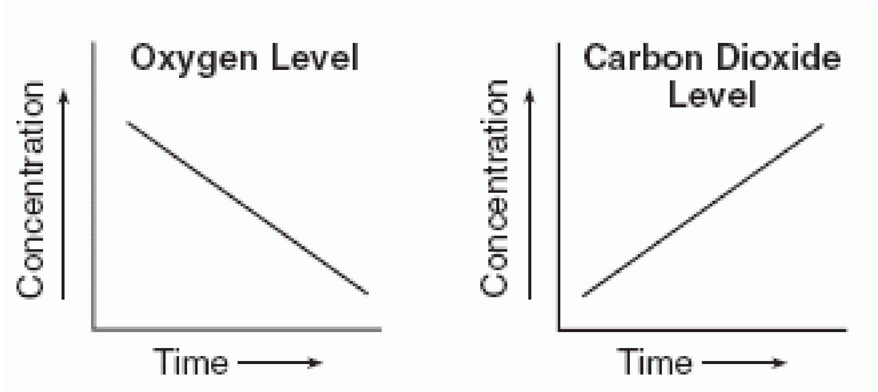
In which population will the greatest number of individuals most likely survive if a significant environmental change related to this trait occurs?

A. 1 B. 2 C. 3 D. 4

24. Which type of organism can obtain energy directly from any of the other organisms in an ecosystem?

A. herbivore B. decomposer C. producer D. carnivore

25. The graphs below show the changes in the relative concentrations of two gases in the air surrounding a group of mice.



Which process in the mice most likely accounts for the changes shown?

A. active transport

B. evaporation

C. respiration

D. photosynthesis

26. A stable ecosystem would *not* contain

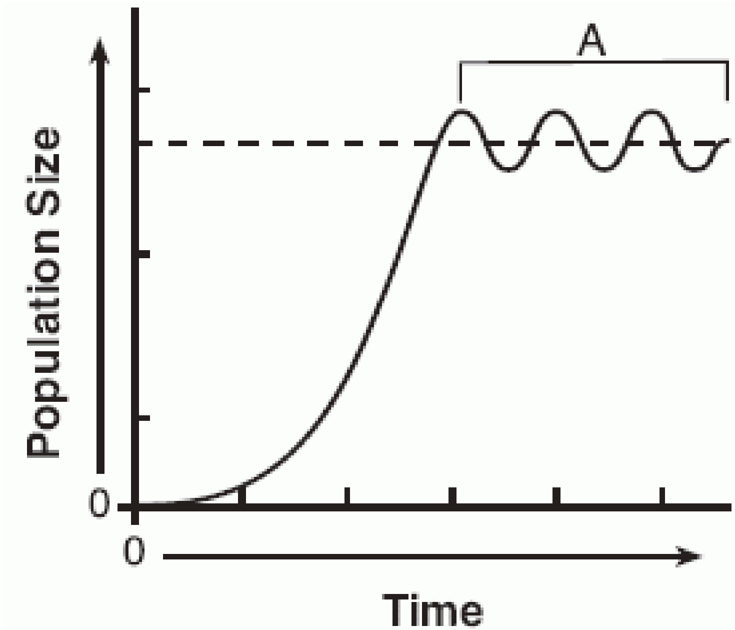
A. materials being cycled

B. consumers without producers

C. decomposers

D. a constant source of energy

27. The graph below indicates the size of a fish population over a period of time.



The section of the graph labeled *A* represents

A. biodiversity within the species

B. nutritional relationships of the species

C. a population becoming extinct

D. a population at equilibrium

Appendix B

Ecology Vocabulary Match Quiz

Match the vocabulary term with the correct definition.

____ 1. ecology

____ 2. organism

____ 3. abiotic components

____ 4. biotic components

____ 5. biosphere

____ 6. population

____ 7. community

____ 8. ecosystem

____ 9. niche

____ 10. habitat

Definition

a. living organisms in the environment

b. physical environment to which an organism has become adapted

c. populations of different species that live in the same area and interact with one another

d. scientific study of the interactions of living things with each other and their environments

e. role of a species in its ecosystem

f. areas of Earth where all organisms live

g. life form consisting of one or more cells

h. natural unit consisting of all the living organisms in an area together with all the nonliving physical factors of the environment

i. nonliving physical aspects of the environment

j. organisms of the same species that live in the same area and interact with one another

Appendix C

Grading Rubric: STEAM Vocabulary Oral Exams

Category	Criteria	Excellent (4)	Proficient (3)	Basic (2)	Needs Improvement (1)
Vocabulary Usage	*Correct Usage of Terms*	Uses all required vocabulary terms correctly and appropriately	Uses most vocabulary terms correctly and appropriately	Uses some vocabulary terms correctly, but with some errors	Uses few or no vocabulary terms correctly
Pronunciation	*Clarity and Accuracy*	Pronounces all vocabulary terms clearly and accurately	Pronounces most vocabulary terms clearly and accurately	Pronounces some vocabulary terms correctly, but with noticeable errors	Pronounces few or no vocabulary terms correctly
Fluency	*Flow of Speech*	Speech is fluent and natural, with no hesitation	Speech is mostly fluent, with minimal hesitation	Speech is somewhat fluent, but with frequent hesitation	Speech is not fluent, with constant hesitation
Comprehension	*Understanding of Terms*	Demonstrates complete understanding of all vocabulary terms	Demonstrates good understanding of most vocabulary terms	Demonstrates partial understanding of some vocabulary terms	Demonstrates little or no understanding of vocabulary terms
Contextual Usage	*Application in Context*	Uses vocabulary terms correctly in various contexts, showing deep understanding	Uses vocabulary terms correctly in some contexts	Uses vocabulary terms correctly in limited contexts	Uses vocabulary terms incorrectly or not at all in context
Response to Questions	*Accuracy and Completeness*	Answers all questions accurately and completely using appropriate vocabulary	Answers most questions accurately and completely using appropriate vocabulary	Answers some questions accurately but lacks completeness or proper vocabulary	Answers few or no questions accurately, lacking appropriate vocabulary
Confidence	*Confidence in Delivery*	Shows high confidence and speaks without prompts	Shows good confidence, with minimal prompts needed	Shows some confidence, but relies heavily on prompts	Shows little confidence, needing constant prompts
Engagement	*Interaction and Engagement*	Engages fully with the examiner, maintaining eye contact and responding appropriately	Engages well with the examiner, with occasional lapses	Shows limited engagement with the examiner	Shows little or no engagement with the examiner

Appendix D

The Science of Ecology – Exit Ticket

True or False

Write true if the statement is true and false if the statement is false.

_______ 1. Ecology is usually considered to be a branch of biology.

_______ 2. The environment of an organism includes only nonliving physical factors.

_______ 3. The biosphere extends from sea level to about 11,000 meters above sea level.

_______ 4. An important ecological issue is the rapid growth of the human population.

_______ 5. A community is the biotic component of an ecosystem.

_______ 6. An ecosystem is always closed in terms of energy.

_______ 7. An ecosystem depends on continuous inputs of matter from outside the system.

_______ 8. Organisms that depend on different food sources have different niches.

_______ 9. Mammals that live in very cold habitats must have insulation to help them stay warm.

_______ 10. Different species cannot occupy the same niche in the same geographic area for very long.

_______ 11. Field studies refer to the collection of data in a field, meadow, or other open area.

_______ 12. Ecologists use inferential statistics to describe the data they collect.