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Use of Inquiry-Based Learning in a Content-Based Physical Science Course for English Language Learners

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USE OF INQUIRY-BASED LEARNING IN A CONTENT-BASED PHYSICAL SCIENCE COURSE FOR ENGLISH LANGUAGE LEARNERS

by

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CHAPTER ONE

Introduction

Twenty-eight students. Eleven ethnicities. Nine different languages. One classroom.

This is the growing reality in many urban school districts. The population of non-native English speakers is increasing substantially in many parts of our country. Because of this, the need for effective English language learner (ELL) education is in high demand. Of growing significance is content-based ELL instruction, in which ELL students learn English language skills congruently with core content such as science, math, or social studies.

I teach a content-based ELL physical science course at a large public school in a large city in the upper Midwest. During my years of teaching this course, I have sought to improve the rigor and richness of the course, both in the science topics that I cover as well as the English language expectations that I have for students in the class. I incorporate inquiry-based learning (IBL) experiences into these classes because I strongly believe that shared experience can be a driving force for language acquisition and that using inquiry methods allows students to think more deeply and critically about core science content. This capstone will examine this question: How can inquiry-based learning be used in a content-based science class for English language learners?

In this chapter I will develop a rationale for exploring this question by examining my personal connection to the topic. I will start by describing the relevance of ELL instruction in my district. Next, I will present a discussion of the legal basis for providing effective ELL instruction. Then, I will provide a brief description of content-based instruction as it is defined by the Minnesota Department of Education. I will then discuss the importance of providing effective ELL science instruction as it relates to the increasing demands of current graduation requirements. Next, I will describe my personal connection to the topic through my own path to teaching, my work in ELL science classrooms, and my relation to learning through inquiry. Then, I will discuss my reasons for connecting ELL instruction and IBL as well as the ways in which IBL can improve ELL science instruction.

ELL Relevance in My District

My school district is located in a part of the country that is home to one of our nation's largest and most diverse immigrant populations. Some information about the current composition of the student body in the district and the surrounding area is provided below (SPPS, 2012):

- Students in the district speak more than 100 languages and dialects.
- The metro area has the largest population of both Somalis and Hmong in the U.S.
- Overall, the area is home to the largest Tibetan population outside of Tibet and the second largest Southeast Asian population.
- The region is experiencing a rapid increase in Hispanic/Latino immigration.
- A much higher percentage of the state's immigrants come as refugees than the national average (about 24 percent compared to 8 percent nationally).

My district has a vested interest in providing high quality ELL instruction for the multitude of children who enter the system with little or no English language skills. Some students are themselves immigrants while others are children of immigrants who speak a language other than English in the home. Though this creates a richness of diversity in our community, limited English skills are a disadvantage that puts ELL students' academics behind those of their non-ELL peers and leads to further inequality in the achievement gap. English language learners possess the capability and aptitude to learn course material at a high level, and, when given effective support in language development, can achieve academic success. Because the lack of English language skills creates this inequality, it is crucial that the district address the need for language instruction for these students.

Legal Basis for ELL Instruction

In 1974, the U.S. Supreme Court decided the Lau vs. Nichols case. This case stemmed from a situation in San Francisco in which only a portion of Chinese students were given English instruction due to a lack of funding. The Supreme Court ruled that this failure to provide the opportunity to close the language gap violated Title VI of the Civil Rights Act. Effectively, this case required schools to provide services for English language learners. The Court concluded that "basic English skills are at the very core of what these public schools teach" (Alexander and Alexander, 2009). Additionally, the Minnesota Legislature passed the "Education for Limited English Proficient Students Act (LEP Act)" in 1980. The LEP Act provided legal definitions for limited English proficient students, general requirements for programs, aid authorization, teacher licensures, and parental rights. Both the Lau vs. Nichols decision and the LEP Act have provided the general framework for the services currently provided to ELL students.

Due to the requirements of Lau v. Nichols, districts have enacted a multitude of programs that are designed to support ELLs throughout the educational process. These programs vary in their target age level, English language level, native language focus, extent of immersion in English language, and language instructional models. One of these models is content-based ELL instruction.

Content Based ELL Instruction

As described by the Minnesota Department of Education, the content-based instruction (CBI) approach uses instructional materials, learning tasks, and classroom techniques from academic content areas as the vehicle for developing language, content, cognitive and study skills. Students participate in core content classes – science, social studies, and math – while simultaneously receiving English language instruction through the natural topics of the core content course. The department further describes effective content-based ELL instruction not as a "sink-or-swim" experience for ELLs, but instead states that

> content-ESL [ELL] favors material that is calibrated to the linguistic needs of students, classes that are sensitive to the previously acquired knowledge they bring to the process, recourse to their native language when necessary, activities that promote active learning, and assessment that accurately measures their levels of accomplishment. Like language acquisition itself, content-ESL is an intricate interweaving – of language and subject matter, of learning theory and learning strategies, of conventional practice and innovation. (MDE, 2001)

This capstone will take an in depth look at that "intricate interweaving" of the learning that takes place in a content-based ELL classroom by examining the cooperative nature of ELL instruction and inquiry-based learning.

Importance of Effective ELL Instruction

The importance of offering content-based ELL instruction is amplified by new graduation requirements, specifically in the area of science. All students, in order to graduate, must earn three years worth of science credit, one year of which must be biology. However, starting with the class of 2015, the other two years must include one year of chemistry or one year of physics. The content-based ELL physical science course, when taught by a teacher with a full-time science license, fulfills one of the years of science credit. With the new requirements, the ELL students will now need to successfully complete a physics or chemistry course in addition to the previously required biology course. Because of this change, many schools have begun to offer content-based biology, chemistry, and physics classes, so developing effective curriculum for these classes is crucial. Furthermore, more responsibility falls on the entry level ELL physical science courses to engage students and teach the fundamental skills necessary for learning science. It is imperative to those students' success that the content-based classes are effective at both instructing the core content as well as English language development.

Improving content-based ELL science instruction can have much broader social outcomes than just helping students meet new graduation requirements. Many of these students come from backgrounds that represent some of the toughest social situations on

Earth. The use of science, technology, and engineering can provide solutions to the issues that brought these students to the United States in the first place. Providing an engaging, rich, and rigorous science curriculum to these students ensures that we are not missing out on the vast collective knowledge of this group of people, and it casts a wider net for finding those key individuals that will truly impact our planet.

My Connection

The high school I teach at is one of the most racially and ethnically diverse schools in the state. About 40 percent of the students are labeled as English language learners. This equates to approximately 800 students. We offer ELL instruction for students from ELL level 1 through ELL level 4. Some courses are "sheltered" ELL in which all students in the course are ELL and the class is taught by a licensed ELL teacher. Some courses are co-taught with a licensed ELL teacher partnering with a teacher licensed in the content area of the course. At level 3, ELL students are mainstreamed with non-ELL students and given support outside of the class. I play a direct role in this system as I currently teach a level 2 ELL physical science class as well as co-teach an ELL level 3 chemistry class. Both of these courses would be considered content-based ELL instruction models. For this capstone, I am going to focus on the level 2 ELL physical science, as that curriculum is somewhat more open-ended, and the course is less developed at my school.

My Path to Teaching

To put my educational background simply, I grew up on a dairy farm. Much of my learning and teaching style has been shaped by the "learning by doing" experiences that I had working on the farm during the time I was in school. My parents did a fantastic job balancing my responsibilities on the farm with high expectations of academics and social life. I was a successful student throughout elementary and high school, and I chose to go on to college at the University of Wisconsin-Madison.

It took me several semesters to figure out what I wanted to do with my time at UW-Madison. I ultimately decided to study Animal Science with a focus in International Agriculture. I have always been interested in the idea of an international community. My parents met during their time in the Peace Corps while living in Ecuador. Because of their worldview, I experienced from a young age the richness that is offered through international and multicultural relationships. We always had family friends from other parts of the world, and I was lucky enough to have the opportunity to travel to South America several times before graduating high school. I felt that a college major that merged Animal Science and International Agriculture was a perfect fit for me. As I neared the end of my undergraduate studies, I began to prepare myself for the next step, which I had always assumed would be veterinary school.

As part of the International Agriculture focus, I was required to have a study-abroad experience. I chose to do a summer semester at a vet school in Valdivia, Chile. I participated in a great program that offered the opportunity to work in multiple facets of the vet school. One of the programs included field work that involved visiting small farms and teaching the farmers the latest techniques in agriculture. I loved working with people. Furthermore, living with an international community of study-abroad students and using Spanish both in and out of school provided me with a love for, and respect of, the “international experience.” At some point during this experience, I realized that my passion was not in working with animals, but in working with people and sharing knowledge that enriches their lives.

When I returned for my final year at UW-Madison, I could feel that my resolve for going on to vet school was weakening. I was not certain that that was the path that I wanted to follow. I began to search out other options that would broaden my experience working with people in need. After exploring several options in the world of teaching, I decided to apply for a program called the Teaching Fellows. This program is part of the larger New Teacher Project and is an alternative licensure path to a career in teaching. After being accepted to the program, I planned on teaching for a year or maybe two, then returning to my original plan of vet school. I am now starting my seventh year of teaching.

Teaching ELL Science

The purpose of the Teaching Fellows is to place well-qualified candidates in historically high-need teaching position – science, math, special education, and dual-language. I chose to pursue a license in chemistry, as my Animal Science major offered a strong background in biochemistry. I was part of the first cohort to go through the Teaching Fellows program in my district. As such, there were a few times when miscommunication caused some confusion within the program. Our agreement with the district was that we would be placed at a school in the district for our first year. However, the district did not have any chemistry positions that were open, and as such, I worked in various schools in the district as a substitute teacher for the first few weeks of the year.

After a few weeks of bumping from school to school, I was picked up full time by my current high school as a general science teacher, and taught a mix of different classes for the first quarter. Because of a higher-than-expected enrollment of ELL level 2 students, the need arose to form two section of ELL level 2 physical science. Because I did not really have a fixed position in the department, and because, frankly, no one else wanted to do it, I picked up those two sections for the remainder of my first year. I continued on to teach two sections of that same course the following year. Due to some changes in the science department, I took a hiatus from ELL physical science for a number of years. Currently, I am back in the ELL Level 2 physical science classroom, and I again have two sections of about 28 students each.

Teaching Inquiry-Based Science

I have always been drawn to the concept of inquiry-based learning. I have gravitated toward inquiry-based instruction because of my learning experiences growing up on a farm. Much of what I learned on the farm was “learning by doing.” There was usually a set goal but the paths I could take to reach that goal were entirely up to me. In addition, most of my learning came from hands-on experience. The questions I developed arose during learning as opposed to at the beginning of learning. I can see that as I teach, I find my most effective lessons and activities follow that model: starting with and experience and then developing the questions.

I have come to consider inquiry-based learning as a spectrum of classroom models that range from simple hands-on activities to completed student-designed curricula. I think that all parts of this spectrum can play an effective role in a course.

Inquiry-based learning models have been employed across all core content areas and all age levels. I think that inquiry-based learning is especially applicable to teaching the sciences, as these courses naturally offer a vast range of opportunity and inception points for the inquiry process. One goal of this capstone will be to discuss the range of inquiry-based learning models and employ them in a science curriculum.

The Overlap of ELL Science and Inquiry-Based Learning

An idea that struck me from the moment that I began teaching ELL science is that there exists a strong overlap between teaching ELL Science and teaching inquiry-based science. This notion came to me based on my personal experience of learning Spanish. I took three years of Spanish in high school, during which I did a fine job of passing spelling quizzes, vocabulary tests, and short skits. Despite learning how to conjugate verbs, correctly pronounce accents, and listen for tenses, not only was I far from fluent, I could barely carry on anything more than the most basic of conversations. That changed for me when I got the opportunity to visit Argentina as part of an exchange program after high school.

Despite the efforts of my Spanish teachers to create context for our learning, memorizing vocabulary words outside of an authentic experience was useless for my true acquisition of the Spanish language. During my trip to Argentina, I was given a reason to learn the language. My experience necessitated the learning of vocabulary, verbs, and tenses that allowed me to express my thoughts related to the exchange experience. Being immersed in the language obviously played a role in the learning of the language, but I return again and again to the importance of experience, especially shared experience, in the development of my Spanish language skills.

Our ELL students are in a similar situation. They are, by choice or not, immersed in the English language upon arrival to the United States. At its core, the science content-based ELL classroom is designed to teach English language acquisition though the lens of experiences in science. I believe that inquiry-based science instruction plays an important role in creating a shared experience through which English language acquisition can occur. These experiences, if used effectively, create a purpose for the students to improve their English.

<u>Improving ELL Science Instruction through Inquiry-Based Learning</u>

This capstone will explore how methods of inquiry-based learning can be employed in the ELL science classroom. Using inquiry-based methods in ELL science will improve the class in several ways.

Currently many secondary-level, content-based ELL classrooms take on a very elementary feel. Many of the available materials and activities seem geared for elementary students, and this turns some secondary students away from learning the material. Many of my students are seventeen, eighteen, and nineteen years old; being treated like you are a "little kid" is disagreeable to anyone, especially young adults. I also think that good inquiry-based lessons provide immediate engagement for the student. From the beginning of the lesson, the student is already developing questions about the activity or experience. Inquiry-based lessons will allow for deeper learning of content goals. The tendency of current ELL science curricula is to simply shorten or remove content from the regular education model to make room for the time required to include language instruction. Because inquiry-based learning includes the students' own line of questioning, students have the opportunity to delve deeper into a given topic rather than just covering the material. Finally, the inquiry methods used can include language goals that explicitly describe the expected outcomes for language acquisition for a given activity or unit.

Chapter Summary

The population of non-native English speakers in our nation is growing. This is especially true in the school where I teach two sections of ELL Level 2 physical science. Because of increased state-level requirements, these students need a strong content-based ELL curriculum that provides them with the necessary skills, both in science and language, to pass those classes. Engaging the population of ELL students in a solid study of science can have lasting social impacts that reach well beyond the walls of our schools.

How can inquiry-based learning be used in a content-based physical science class for English language learners? Because of my upbringing and educational background, I feel a strong connection both to ELL education as well as to the inquiry-based learning model. Using inquiry-based techniques in a content-based ELL science classroom could enhance the learning experience for students, not only in the science content but in the language acquisition as well. In this capstone, I will explore the relationship between ELL science instruction and inquiry-based learning by developing a curriculum for an ELL Level 2 Physical Science course.

In the following chapter, I will present a literature review that will delve into the topics of CBI and IBL. I will begin be discusses several theories of language acquisition that provide the framework for CBI. Then, I will define CBI, discuss how CBI has been used in different settings, and show the effectiveness of CBI in teaching language and content. Next, I will define IBL and show the uses and effectiveness of several different models of IBL. Lastly, I will explore how IBL has been used in ELL instruction in the past, and I will discuss how IBL should be modified to support the needs of ELLs.

CHAPTER TWO

Review of Literature

Introduction

There are more than five million English language learners (ELLs) enrolled in public schools in the United States. This represents over 10% of all public school students, and this number is growing rapidly. From 1997 to 2007, growth of ELL enrollment exceeded that of overall enrollment by more than six to one (NCELA, 2010). Regardless of where they teach, science educators will undoubtedly encounter ELL students in their classrooms and be expected to effectively teach science content to these students. Many state and national science standards advocate for the use of inquiry in science teaching for all. Can this be done for students who are not fluent in English?

This capstone will present a physical science unit that incorporates concepts from a content-based instruction (CBI) curriculum as well as inquiry-based learning (IBL) curriculum to answer the question: How can inquiry-based learning be used in a content-based science class for English language learners?

This chapter will rationalize the question of this capstone by first addressing the theories of language acquisition through experience: The Interaction Hypotheses, The Output Hypothesis, The Limited Capacity Hypothesis, and The Cognition Hypothesis. Next, the concept of CBI will be explained. That section will also address the effectiveness of CBI as well as show cases in which CBI has been introduced in different settings. Then, the concept of IBL will be defined, and a description of the different models of IBL will be included. Finally, I will show how IBL has been used in ELL instruction in different ways.

Language and Experience: Task-Based Language Learning

A concept that is often mentioned in the discussion of language acquisition is the importance of experience to the learning of language (Jackson, 2013; Robinson, 2011). According to Colburn and Clough, "Giving students direct experience with a concept before providing verbal instruction is critical in helping them relate the verbal abstractions to more meaningful concrete experiences" (1997, p. 30). Bollinger (as cited in Bergman, 2011) further mentions that this constructivist-based approach can increase student engagement and critical thinking. When implementing experience-based language learning solutions to meet the growing challenge of ELL education, it is crucial to include consideration of theories of language acquisition.

Task-based language learning is a theory that has been developed over the last 30 years to incorporate the benefits of experience for the learning of language (Robinson, 2011). In this theory, the tasks that are presented to students help to create experience that lends itself to the development of language necessary to process the event that was experienced. As Prabhu puts it:

> task-based teaching operates with the concept that, while the conscious mind is working out some of the meaning-content, a subconscious part of the mind perceives, abstracts, or acquires (or re-creates as a cognitive structure) some of the linguistic structuring embodied in those entities, as a step in the development of an internal system of rules. The intensive exposure caused by the effort to work

> out meaning of content is thus a condition which is favorable to the subconscious abstraction—or cognitive formation—of language structure. (1987, pp. 70–71)

The idea of language acquisition through experience, or task-based language learning, has led to the development of several theories that describe the ways in which task and experience can promote the development of second language acquisition.

Theories of Language Acquisition through Experience

In this section, I will discuss several theories that relate language acquisition and experience. These theories include: The Interaction Hypotheses, The Output Hypothesis, The Limited Capacity Hypothesis, and The Cognition Hypothesis. Each of these theories presents an argument that supports the coupling of language teaching to direct experience and tasks through which the language is taught. These theories form the basis of CBI and rationalize its use in language instruction classrooms.

Included in the descriptions of these theories are several key terms related to the field of language teaching. Input language refers to the literacy skills used by students to receive content of learning. Input language tasks include reading skills, decoding and comprehension, as well as listening skills. Both of these areas require vocabulary knowledge for learners to create meaning. Output language refers to the skills used by students to communicate their understanding. Included in output language are writing and speaking. Improving these skills—reading, listening, writing, and speaking—form the foundation of language teaching in any setting. The theories discussed below argue that pairing the teaching of those skills with direct experiences and tasks promotes the acquisition of a second language.

The Interaction Hypothesis and Focus on Form. Long (1989) argued that the interaction that takes place when language learning is paired with task work promotes language acquisition because it provides a way to make the input language more comprehensible. Furthermore, the experience provides a context through which the learner can practice the forms that language takes through the input and output of the task (Robinson, 2011). Robinson (2011) also referenced work by Keck et al. and Mackey that shows that the attention that the learner is required to give to second language form can speed the learning of language form relationships and prompt first- and second-language exchange.

The Output Hypothesis. The Output Hypothesis specifically draws attention to the language acquisition that takes place as a learner tries to produce meaning in the second language about the experience or task. Swain (1995, pp. 125–126) argued that focus on output facilitates second language acquisition because "in producing the target language . . . learners may notice a gap between what they want to say and what they can say, leading them to recognize what they do not know, or know only partially." The attempt to produce second language form offers learners opportunities for testing their current understanding of second language forms and promotes cognitive reflection about the production of second language output (Robinson, 2011).

The Limited Capacity Hypothesis. Language learners have a limited cognitive capacity to "notice" what they are learning. This concept has been referred to as the Limited Capacity Hypothesis. The extent to which this is true of second language acquisition is an important issue to consider for the design of materials and instruction in classrooms (Robinson, 2011). Schmidt (1990, p. 143) notes that "Task demands are a powerful determinant of what is noticed. The information committed to memory is essentially the information that must be heeded in order to carry out a task." This hypothesis, therefore, suggests that when pairing experience with language learning, it is crucial to consider what the learner is noticing, and care should be taken when determining the demands of tasks, both in content and in language. Placing higher demand on content tasks may limit the ability of a learner to commit to memory language forms and vice versa.

The Cognition Hypothesis. The Cognition Hypothesis differs slightly from the Limited Capacity Hypothesis, because the Cognition Hypothesis provides a rationale for sequencing tasks and experiences solely in order of increased cognition demand within a language instruction model. Because this sequencing mirrors the natural order of cognitive demands that children meet during their first language acquisition, the Cognitive Hypothesis suggests that those sequences provide optimal support for second language acquisition. Increasing complexity in content tasks and experiences offer learners the opportunity to attempt to use accurate and complex language at the level needed to meet real-world target task demands (Robinson, 2011). As Robinson states, "learners do not trade-off attention to accuracy against attention to complexity of production: Rather, on some dimensions of task demands increasing complexity is argued to promote more accurate, grammaticized production and more complex, syntacticized utterances." (2011, p. 14)

Each of these theories—The Interaction Hypotheses, The Output Hypothesis, The Limited Capacity Hypothesis, and The Cognition Hypothesis—provide a rationale for pairing language learning with experience. The meshing of experience and language acquisition provides a learning environment that is mutually beneficial to learning language and content. Content-based instruction is an educational model that seeks to capitalize on this concept: provide a content experience through which the development of language can occur.

Content Based Language Instruction

There exists a daunting challenge in the current educational system: ensuring that ELLs meet the growing social, academic, and civic demands of the 21st century. Because the academic performance of ELLs is consistently behind that of their peers, there is need for change in ELL education (Koelsch, 2014). Content-based language instruction (CBI) provides a framework through which this change can occur.

In this section, I will begin by defining content-based language instruction. I will show how CBI can be used to connect experience to language learning in the science classroom. Next, I will include a discussion on the importance of maintaining a focus on language standards in CBI models. Then, I will include a description of how CBI models have been used in different levels of education. Finally, I will show how past implementations of CBI have been effective in improving the language acquisition of students.

Defining content-based language instruction. Content-based language instruction (CBI) refers to the integration of school or academic content with language teaching objectives. The CBI model differs from traditional language instruction. In CBI learners work to master both content and language goals through a reciprocal process that promotes understanding and conveying of varied concepts through their second language (Burger, 2001). Brinton, Snow, and Wesche (2003) characterize CBI as “the concurrent study of language and subject matter, with the form and sequence of language presentation dictated by content material” (p. ix). As characterized by Kong (2009) in the work of Halladay and Wells, CBI is an integrated view of learning that takes into account human learning as a meaning-making process, and that making meaning involves the use of language to conceptualize new information. Humans simultaneously engage in learning language and learning through language. CBI provides a setting in which this learning of language and learning through language promotes understanding of both content and second language acquisition.

<u>Content-based Instruction use in science.</u> The learning of science content inherently includes the need to learn new language, both for native English speakers as well as English language learners (ELLs). Quality science instruction connects concepts to previous experiences, whether in or out of school. In order to support ELLs’ language acquisition, including academic language inputs (reading comprehension, word recognition, vocabulary mastery) and outputs (writing, speaking), teachers must deliberately connect content experience to language in science. This starts by building upon learners' prior experiences such as personal memories, cultural upbringing, and natural phenomena. In addition, through CBI, teachers are able to provide ELLs with firsthand encounters and experience with science content. This is especially important for

ELLs. Within the CBI context, teachers provide multiple avenues thorough which to create these experiences: current news or popular culture, cooperative work, discrepant events, and laboratory investigations (Bergman, 2011).

Using CBI to address language standards. An important aspect of CBI is to intentionally provide focus on language standards. Often, the great emphasis placed on grade-level academic content learning goals in the curriculum materials used in CBI, can blur the lines between the roles of a content teacher and a language teacher (Pica, 1995). Bigelow, et al. (2004) argued for the need for CBI teachers to maintain a strong hold on their role as language teachers. For CBI to work to its maximum potential, a concerted planning effort must be made to address language objectives. Furthermore, it is imperative to combine those objectives with effective instructional strategies that target and assess student performance in language acquisition. To this end, Bigelow, et al. (2004) proposed a flexible and dynamic planning model for content-language integration, called the Connections Model. The Connections Model provides a means of conceptualizing a CBI model that has the flexibility needed to facilitate language teaching in a range of settings and works to address the challenges CBI faces in losing the language as content objectives predominate in the instructional process.

CBI use in different educational settings. Factors such as program objectives and the practical outcomes of differing contexts have led to a wide range of CBI models that have been implemented in diverse educational settings (Kong, 2009). Met (1998) describes the variety of approaches to integrating content and language in CBI as a continuum. This continuum ranges from a content-driven end to the language-driven end.

Different models of CBI fall on this continuum based on the desired balance between content learning and language learning. The CBI curriculum that was developed for this capstone sought to maintain an even balance between content and language.

Whatever the balance is between content and language along the continuum, CBI models are characterized by a commitment to curriculum objectives for both content learning and language learning. The following subsections provide three examples of the wide range of use of CBI in different educational settings.

CBI in elementary education. Research by Trube (2012) offers insight into the use of CBI in elementary classrooms from a wide ranging analysis of language development programs in China. One of the recurring themes in these classrooms was the use of cooperative learning to help promote development of content learning and language learning. In many of the CBI elementary classrooms, teachers carefully balanced the various student groups by differing ability levels. The observations of this study suggested that cooperative learning improved the students' self-esteem, understanding of tasks, and skills in working with others.

Cooperative learning seemed to lead to social cohesion within groups, which allowed students to overcome their fears of speaking English in front of others. As students became more confident and trusting, their language output increased, and they practiced more frequently. Several teachers referred to the influence of Vygotsky and the understanding that learning is a social activity and a tool for constructing meaning. One teacher reflected the following: "[The English] language is not only explicitly taught but is also the medium of curriculum instruction. From this point of view, it makes possible for child learners to combine language learning with social situations, thus building up direct links between linguistic symbols and the target objectives.” (p. 25)

CBI in middle school education. A study by Kong (2009) investigates four different middle schools lessons taught using different CBI models. These models varied in the balance between content focus and language focus in courses taught by both content teachers and language teachers.

Lesson One involved a cyclical model taught by a content teacher. In this model, there was only one content learning objective, which the teacher stated at the beginning stage of the lesson. The other stages and activities of the lesson all revolved around this objective and the teacher explicitly made the connection clear to the students. In Lesson One, the teacher did not explicitly teach language objectives, but the language teaching took places through the complex forms and skills needed to understand the complex nature of the content.

Lesson Two was also taught by a content teacher and exhibited a cyclical model that focuses on a cause-effect content objective. In this lesson, however, the teacher explicitly taught language necessary to discuss this cause-effect relationship. For example, the teacher told students, “But please remember when you try to write these…in your answers, you need to use ‘therefore,’ and use complete sentences, or you can say ‘result in’ or ‘lead to’ in order to link the several phrases together” (p. 244).

Lesson Three exhibited a language teacher’s use of language objectives to teach the content object of cause-effect and hypothesis. The teacher focused on the language relationships between cause–effect and hypothesis, for example, conditional "-if" statements, to support students' learning of the two content objectives.

In Lesson Four, a language-trained teacher presented the same content as covered in Lesson One. However, the content complexity was much lower than in Lesson 1, because the teacher focused on lower level language functions due to the lower language proficiency of her students. In contrast to the complex knowledge relationships of cause–effect, comparison, and definition involved in Lesson 1, the teacher in Lesson 4 presented content simply as a description of a sequence of events, which was reflected in her use of the connectives of "and then" and "so." The teacher also worked on drilling pronunciation of a few new words, but did not address the subject-specific definitions of those words. Because the content was so much simpler, the language use was correspondingly less complex.

The findings from the analysis of the four CBI lessons provide some insights into what may be more effective content and language pedagogies that better support content and language learning in the elementary context. Analysis of the lessons shows that a focus on content provides a strong foundation for CBI. These findings support Brinton et al.'s (2003) contention that in CBI, "the form and sequence of language presentation [should be] dictated by content material" (p. ix). Kong goes on to mention that the findings of the study do not mean, however, that any pedagogical model that has the content as its basis will be effective. The findings of this study suggest that the new content has to be explored in-depth and from different perspectives to enable complex knowledge relationships to be co-constructed by the teacher and students through the use of correspondingly complex language.

CBI in community college. Santana-Williamson (2012) describes her experience in integrating a CBI curriculum at a small community college in the southwestern U.S. near the U.S.-Mexico border. The course was an integrated skills program designed for students who have a certain level of everyday linguistic and socio-linguistic competence and who want to enroll in college classes in the future. At first, the ELL program offered only one path, a grammar-based, skill-based three-semester program, which the author felt only partially addressed the needs of its ELL community.

To address the greater needs of the ELLs to prepare for future academic content classes, Santana-Williamson developed a task-centered lesson planning model. In this model, every text, either oral or written, was approached with an academic task in mind. Using tasks as the core of each lesson plan, skills and language that students had to learn to do a particular task or tasks were determined. Two types of learning tasks were developed: academic tasks and scaffolding tasks. Academic tasks focused on the content material challenges. They determined the final outcomes of learning, and from those outcomes, the author was able to determine skills and language needed for those tasks as well as design clear task-based assessments.

The second task category, scaffolding tasks, included activities that were designed to bring students' academic skills and language "up to speed" so they could handle the academic tasks. The series of scaffolding tasks developed students' ability to read and comprehend so they could write with more academic sophistication. Examples of scaffolding tasks included preparing students to read and paraphrase rather than memorize texts, as well as teaching students to identify the essential vocabulary in short paragraphs so they could determine which words were essential to comprehension.

The tasks-model approach presented by Santana-Williamson is one way in which a CBI model can improve the content instruction for ELLs.

Summary. The different models and uses of CBI discussed above show the wide range of potential application and implementation of CBI concepts. The way in which those models are used by educators depends greatly on the needs of the students and the needs of the district. In the following section, I will show the ways in which CBI has been effective in increasing language acquisition for second language learners.

Effectiveness of CBI. While the extent of research on the direct impact of CBI on language acquisition is somewhat limited, studies exist that have shown CBI to positively impact student language acquisition as well as content level achievement. In this section, I will present several studies that show the effectiveness of CBI in academic achievement, cognitive development, and second language development.

Effect of CBI on academic achievement. Among the foremost concerns of critics of CBI is its effectiveness of teaching content through this model. Research by Tedick (2012) supports the claim that CBI is an effective means of teaching academic content. The study mentions work by Genesee, who reported on multiple large-scale studies of French immersion students. The findings presented in that paper consistently indicate that immersion students did as well as or better than non-immersion students on standardized tests of achievement administered in English. As cited in Tedick (2012)

Genesee also reported that immersion students caught up to and often surpassed their non-immersion peers in reading and English language arts achievement.

A study by Caldas and Boudreaux (1999) found that students studying in CBI models in grades 3, 5, and 7 performed significantly better in English language arts and math than their traditional content model peers, regardless of race, grade, gender, or the poverty status of the schools. In fact, this study found that CBI models produced greater results in high-poverty schools, especially with achievement in English.

Effect of CBI on cognitive development. In addition to improving scores on standard tests of language learners, CBI can positively affect students' cognitive development. A study by Jäppinen (2005) focused on thinking and learning processes that develop in integrated content and language instruction. In this study, the author developed four tests to determine the cognitive development of students participating in math and science CBI model courses. This large-scale study of learners ages 7-15 compared the performance of a CBI group of 335 learners being taught in a second language with that of a control (non-CBI) group of 334 students being taught in the first language (Finnish). The findings showed that although there were no significant differences between the CBI and non-CBI groups for learners ages 13–15, the younger CBI students (ages 7–9 and 10–12) significantly outperformed the non-CBI groups on several measures of cognitive development. Jäppinen (2005) concluded that teaching subject areas through a second language supports learners' cognitive development.

Effect of CBI on second language development. According to Kong (2009) CBI has been increasingly shown as an effective curriculum approach to second language learning. According to research on language immersion programs by Genesee and Lyster, studies have consistently demonstrated that CBI students develop much higher levels of functional second language proficiency than non-CBI students as cited in Tedick (2012). Tedick goes on to mention that although research conducted throughout the 1970s, 1980s, and 1990s has documented that immersion students achieve near-native levels of second language proficiency of input skills (listening and reading) their productive (output) language skills are underdeveloped in areas such as grammatical accuracy and complexity. There is an increasing body of study that seeks to understand this deficiency as well as develop models that improve the effectiveness of output language production (Tedick, 2012).

There is some research that shows that CBI models can positively affect output language skills in the area of oral production. A study by Burger (2001) investigated the effectiveness of CBI at the post-secondary level on the oral language development of students in an introductory psychology course taught through a CBI model. This model included adjunct language classes designed to provide support to the students learning in their second language. Students were scored in two task categories of oral language expression: elicited imitation response and a discussion task. The study found that students scored significantly higher ($p < 0.5$) in both task categories' post-tests compared to pre-tests. CBI provides a learning structure that can positively affect oral language abilities for ELLs.

Summary. Through the integration of content instruction and language instruction, ELL students participate in educational practices that not only deepen their understanding of disciplinary concepts, but also lead to sophistication of language use when students engage in disciplinary practices in new situations (Koelsch, 2014). The movement toward including content in language instruction helps to meet the crucial need to prepare ELLs for mainstream academic content instruction or include them in mainstream settings (Bigelow, et al., 2004). The benefits of CBI for ELLs make it imperative that teachers implement CBI structures for ELL instruction effectively and immediately.

Inquiry-Based Learning

Inquiry-based learning is among the core of ideas on which state and national science standards are based. It is a model of learning that is student-centered. Students generate questions, procedures, and explanations based on their areas of interest. This capstone will explore how inquiry-based learning can be implemented in a content-based science course for ELLs.

In this section, I will begin by defining inquiry-based learning. Next, I will provide a discussion of the different models of inquiry that can be used in teaching. Finally, I will present research that supports the effectiveness of different inquiry models.

Defining inquiry-based learning. Inquiry-based learning (IBL) is a concept that has been defined in different ways. Colburn defined inquiry-based learning as “the creation of a classroom where students are engaged in essentially open-ended, student-centered, hands-on activities” (2000, p. 42). While IBL can be carried out in any content area that allows for student to follow a critical line of open-ended questioning, IBL is most commonly found in science classrooms. In fact, IBL is a core thread in many state and national science standards: "Scientific inquiry is central to the learning of science and reflects how science is done" (NSTA 2004, p. 2). In the Minnesota state science standards, the second standard of the Nature of Science and Engineering strand is "Scientific inquiry is a set of interrelated processes used to pose questions about the natural world and investigate phenomena." (MDE, 2015, p. 3)

As cited by Bunterm (2014), Martin-Hansen describes that the processes that students follow in IBL closely resemble the methods of actual scientists in the real world. For example, central ideas of IBL include asking questions about the natural world, gathering evidence, and providing explanations. Buntern (2014) defines IBL in this way:

"One way to conceptualize inquiry-based learning is that it is a student-centric pedagogical approach characterized by activities that encourage the acquisition of both science content knowledge and process skills." (p. 1939)

Or, as Pearce points out (as cited in Jensen, 2011),

"Inquiry science in the classroom helps teachers to meet the students where they are when they come to class… provides authenticity and autonomy affords the students opportunities to do what kids do best: investigate, explore and discover, using their own questions, curiosities, and interests" (p. 5).

An important distinction to make when considering IBL is that hands-on activities alone do not equate to inquiry learning. Bunterm (2014) points out that hands-on activities that can be found in traditional classroom curriculum cannot be referred to as IBL if they are carried out without explicit attention drawn to the research of questions. Providing students with hands-on opportunities does not necessarily mean they are doing inquiry (Gooding & Metz, 2012). Gooding and Metz (2012) reference a study by Minner, Levy, and Century that directly compared two hands-on curricula in which one curriculum included explicit IBL components, and the other included hands-on activities without direct IBL instruction. They concluded that hands-on activities alone did not create significant conceptual change compared to the IBL model. In addition to the hands-on component associated with lab work, IBL investigations involve a great deal of student inquisitiveness that lead to more student questioning and reflection (Gooding & Metz, 2012).

Different models of inquiry. While IBL has played a large role in the development of science curricula for decades, many teachers may still be uncertain about how they can effectively implement IBL in their classrooms (Miranda, 2012). Bianchi and Bell (2008) suggest that one reason for the lack of explicit IBL lessons in the classroom is that inquiry does not refer to a single type of lesson but rather a range of approaches that form a continuum. Researchers have described this continuum as levels that differ in the amount of specific instructions given to students. As described by Bunterm (2014), a four-level model has been proposed to characterize the support that is given to students in the inquiry process. In the first level, the question, procedures, and solution are all provided to the students. At the second level, students are not given the solution. At the third level, both the methods and the solution are not given. At the highest level, students generate information about the question, the procedures, and the solution.

These different levels of IBL can be further categorized in different models. The major models that have been described by researchers are confirmation inquiry, structured inquiry, guided inquiry, and open inquiry (Bunterm, 2014; Miranda, 2012; Bianchi & Bell, 2008). In confirmation inquiry students are given a question, and the results are known in advance. Students' work focuses on exploring the relationship between the question and the results. Structured inquiry happens when the questions and procedures are provided to the students, but students generate an explanation supported by the evidence that they collect. In guided inquiry, the teacher provides the question, but students design the procedures and collect evidence to explain the relationship to the question. Open inquiry consists of students developing questions, developing procedures, carrying out experiments, collecting data and communicating results (Bianchi and Bell, 2008; Miranda, 2012). The curriculum that is developed in this capstone will include elements of guided inquiry and structured inquiry.

Effectiveness of different models of IBL. Although extensive literature exists that compare inquiry approaches against non-inquiry-based approaches, there are only a few studies that focus on differences among various levels of inquiry (Miranda, 2102; Bunterm, 2014). As described in an article by Miranda (2012), Chatterjee, Williamson, McCann, and Peck investigated university students' attitudes towards guided-inquiry laboratories and open-inquiry laboratories. The students were all enrolled in a semester long chemistry course in which students conducted both guided- and open-inquiry experiments. They found that most students preferred inquiry laboratories in which some instructions and procedures were provided instead of open-inquiry laboratories.

Bunterm (2012) examined the effects of guided vs. structured inquiry on secondary students' learning of science. Researchers measured science content knowledge, science process skills, scientific attitudes, and self-perceived stress. In comparison to the structured-inquiry model, students in the guided-inquiry model showed greater improvement in both science content knowledge and science process skills. In the areas of scientific attitudes and stress, students in one school benefited from guided inquiry much more than they did from structured inquiry. The authors attribute the findings to the differences in the degree to which students engaged with the teaching material.

Summary. At the core of any science curriculum is the concept of IBL. Learning through inquiry closely matches the way in which science is conducted and practiced in the real world. The different levels and models of inquiry provide many possible inroads for educators to take when implementing IBL in their classrooms. The different models of IBL have been shown to be effective tools through which to teach science. In the following section, I will discuss how these different forms of IBL have been used in ELL classrooms.

Use of Inquiry-Based Learning in ELL Classes

The traditional approach to the science education of ELLs separates English language development from science content instruction, especially as approached through IBL, because it is assumed that English language proficiency is a prerequisite for science content learning. In this section, I will show a different take on that topic. The self-generated experiences provided through IBL provide a benefit to learners both in language acquisition and content learning, known as the Synergistic Effect. I will begin by defining the Synergistic Effect and describing the ways in which language teaching pedagogy and science content pedagogy overlap. Then, I will provide a discussion on how IBL models can be modified to fit the needs of ELLs.

The Synergistic Effect. While the traditional model of science education of ELLs has largely avoided inquiry approaches, researchers have argued that the integration of inquiry science and language acquisition enhances learning in both domains (Stoddard, 2002). Bergman (2011) argues that there is a mutual benefit to language acquisition and science content learning because there is a pedagogical overlap of IBL and ELL instruction. He defines this overlap as the "Synergistic Effect." Bergman (2011) describes the important aspects of this relationship in the following ways.

Meaningful and memorable materials. Many effective ELL lessons contain the use of visual or hands-on materials. Tangible, relevant items are also necessary for effective inquiry-based learning. The following materials are used in both ELL instruction and IBL lessons: hands-on manipulatives, real-life objects, pictures and illustrations, models, graphs, charts, and multimedia resources such as videos, interactive software, and internet resources.

Learning by doing. The path to fluency in a second language often involves experience in a setting that provides immersion in that language. Similarly, inquiry-based science labs require active student "immersion" in the investigation of science concepts. In IBL students are immersed in the science content by selecting investigative questions, applying math during analysis, defending findings, and reflecting on results. The use of IBL in ELL instruction provides the opportunity to create lasting learning in both science and language.

Opportunities for application of new information. The depth of learning increases when students can apply new concepts and skills: “Application means using or recognizing previous ideas in a new situation” (Colburn & Clough, 1997, p. 33). The application of a new language is crucial to language learners. As Bergman (2011) points out in the words of Echevarria, Vogt, and Short, "For students acquiring a new language, the need to apply new information is critically important because discussing and 'doing' make abstract concepts concrete” (p. 41). The opportunity for science and language application occurs in IBL through the use of research projects, graphic organizers, journal entries, reports, field trips, and group activities.

Student groups and interactions. The application of science and language can be included through the opportunity to interact with peers in activities such as cooperative activities such as role-plays, debates, discussion circles, and the teaching of others. These interactions are useful in both the learning of science and language acquisition. In both cases, students have opportunities to use, review, and refine academic language and vocabulary.

The teacher's critical role. While effective ELL instruction and IBL techniques often discourage the traditional teacher-centered, lecture-dominated classroom, the teacher still plays a critical role to ensure successful student learning when using IBL in ELL classrooms. As Bergman (2011) puts it:

> “Essential teacher behaviors include the following: (1) clear speech, (2) eye contact and welcoming gestures, (3) individualized interactions, (4) open-ended questions, (5) sufficient wait-time I (after teacher question) and wait-time II (after

student response) so all have time to think, and (6) responses that encourage more student contributions ("Tell me more about…") and further critical thinking ("What do you mean by…?") without excess praise or criticism” (p. 42).

Time and student management. The student-centered approach that is favored in ELL classrooms and IBL lessons mean that teachers must be diligent in managing the classroom. Often, fully engaged students lead to a well-managed environment. Teachers should work to provide an entire class period that is focused on appropriate activities and relevant learning. Thus, it is crucial that teachers consider students' unique needs and specific classroom contexts in both ELL classrooms and IBL settings.

Summary. The concept of the Synergistic Effect is summarized by the argument that the use of IBL in ELL science instruction engages ELLs in the exploration of scientific phenomena through language activities which are explicitly linked to objects, processes, hands-on experimentation, and naturally occurring events in the environment. This idea directly links to the language acquisition models discussed in the first section of this chapter. Thus, IBL creates an environment that provides direct experience to ELLs to explore science concepts while concurrently practicing the input and output skills in their second language.

Supporting ELLs in IBL processes. While the Synergistic Effect supports the use of IBL in ELL classrooms, it is important to note that researchers have suggested that ELL students should be gradually released into IBL models rather than immediately moving to open inquiry. Fradd et al. (2001, p. 487) recommend that ELL teachers provide more overall structure to inquiry projects, "beginning with scaffolded explicit instruction and moving to student-initiated inquiry" over the course of the school year. The curriculum presented in this capstone will take into account this consideration, as the use of IBL will be through structured inquiry and guided inquiry.

Summary. The benefits of teaching ELL science through IBL models are based on the idea that the pedagogies of effective language instruction and effective science instruction are closely related. This relationship is known as the Synergistic Effect. While the overlap of these pedagogies provide a strong rationale for using IBL in ELL science instruction, it is important to keep in mind the specific needs of ELLs when implementing IBL into the ELL setting. The curriculum presented in this capstone will take into account these concepts when developing the inquiry lessons included in the unit.

Chapter Summary

In this chapter, I presented concepts and theories found in resources that explored CBI, IBL, and their connected use in ELL instruction. Experience is a key component of language acquisition, as evidenced by several hypotheses of language learning. The benefit of providing content experience to ELLs can be implemented by the use of CBI models in ELL instruction.

CBI is an instructional design that involves the concurrent instruction of content objectives and language objectives. This design has grown in its implementation over the last 30 years as a response to the growing challenge to teach ELLs the increasing educational demands of the 21st century. It is useful to think of CBI on a continuum of instructional models that range from content-driven models to language-driven models.

Different CBI models have been implemented in a wide array of settings, ranging from elementary to post-secondary education. Different forms of the CBI model have been shown to positively affect both the academic achievement and second language acquisition of students.

IBL is a technique that is widely used in science curricula and forms the basis of state and national science standards. Different approaches to IBL vary in the level of instruction given to students in the areas of questions, procedures, and solutions. These different levels have led to the development of different models of IBL: confirmation inquiry, structured inquiry, guided inquiry, and open inquiry.

The use of IBL in ELL classes presents an overlap of pedagogy, known as the Synergistic Effect. Effective methods used in IBL are closely related to the effective teaching practices of ELL instruction. These overlaps provide a firm rationale for the use of IBL in the ELL classroom.

This capstone presents a set of lessons that incorporate different IBL models in a physical science CBI curriculum for ELLs. The lessons that are presented will teach several physical science standards that are included in a physical science course as well as the language standards that have been adopted into the course by my school district. The lessons are not meant to form a single unit by themselves. Rather, they are each intended to play a role in several different units that would be generally taught in a physical science course. Activities in those lessons will incorporate the concepts of IBL in which students generate questions, design procedures, and explain results. Thus, this capstone will answer the question: How can inquiry-based learning be used in a content-based physical science class for English language learners?

In chapter three, I will present the methodology that will be used to create the lessons that answers the question of this capstone. I will include a rationale for these lessons by first providing a description of the setting in which the lessons and activities will be used as well as the participants for whom they are intended. I will include a description of the overview that I will provide for each lesson. Then, I will provide a format for each lesson plan as well as discussion of the theory grounding the lesson format. Finally, I will describe the intended outcomes of the implementation of these lessons.

CHAPTER THREE

Methodology

Introduction

It is important that educators work to meet the challenge of teaching the growing population of English language learners (ELLs) at a high level, both in content and English language acquisition. An effective approach to meeting this challenge has been the implementation of the language teaching model of content-based instruction (CBI). The lessons that are presented in this capstone will serve as examples of how of inquiry based learning (IBL) can be utilized in a content-based physical science course for ELLs.

In Chapter Two, I described the importance of experience in language acquisition. I discussed how CBI is an educational model that incorporates subject specific content goals with language learning goals. I also included a discussion on IBL, which is an instructional model often used in science courses. I described how the effective models of IBL are closely related to effective models for teaching language to ELLs. The following chapter will include a discussion of the methodology I will use to answer the research question: How can inquiry-based learning be used in a content-based science class for English language learners?

In this chapter I will discuss the setting in which the curriculum will be used as well as the participants for whom it is intended. I will provide an outline that describes the way in which the lessons in the unit will be presented as well as a discussion of the theory grounding the lesson format. Finally, I will describe the intended outcomes of the implementation of this curriculum.

Setting, Classrooms, and Participants

In this section, I will describe the school setting in which I work, as well as the classroom participants for whom these lessons were designed. I will explain how a standardized language proficiency test is used to place ELLs into language proficiency levels that lead to different support structures for students.

Setting. The high school in which I work is located in a large city in the upper Midwest. I have worked at the high school for seven years. It has the largest student enrollment, 2077 students, of the six high schools in the district where it is located. As of the 2013-14 school year 53% were Asian American, 21% were African American, 15% were Latino American, 9% were Caucasian, and 2% of students were American Indian. There were also 38% of students that were classified as English language learners and 85% were eligible for free and reduced lunch.

Classroom. This curriculum is intended for use in two sections of a content-based physical science course for ELL students. These classes are taught by a teacher holding a science license, so students are able to receive credit for one year of science to fulfill the state required three years of science. There is also an Educational Assistant in each class. Classes meet daily for either 43 minutes or 47 minutes depending on the day of the week. Each class is made up of approximately 30 students with a mix of ages (14-18 years old) and grade levels (9^{th} – 12^{th} grade). The reason for these wide ranges in age and grade level is because the class roster is determined by ELL Level. These classes are made up of students at ELL Level 2 English proficiency.

Participants. The lessons have been designed for Level 2 ELLs, which means that they are at the “beginning” stages of English language proficiency, as defined by the World-Class Instruction and Design Assessment Consortium (WIDA) test for English language proficiency. In my district, ELL students are classified in levels based on their English language proficiency skills as assessed by the Assessing Comprehension and Communication in English State-to-State for English Language Learners (ACCESS for ELLs). This large-scale test is used by many districts across the nation to assess the English language development levels of ELLs, and it forms the core of the district’s approach to instructing and placing English language learners in appropriate courses. These standards incorporate a set of model performance indicators that describe the expectations educators should have of ELL students at four different grade level clusters and in five different content areas. Students are assessed within each grade level cluster and content area in four language domains: listening, speaking, reading, and writing. The outcomes of the ACCESS for ELLs are used to place ELLs into different language proficiency levels. The language proficiency skills of each level are summarized by the WIDA consortium as follows:

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Entering	Beginning	Developing	Expanding	Bridging	Reaching

Thus, students in the course for which this curriculum has been designed are at the "beginning" stages of English language proficiency (ACCESS, 2014).

Presentation of the Lessons

In this section I will discuss the format in which I presented each lesson in the unit. For each lesson, I gave an overview of the lesson as a whole, including a description of the unit in which the lesson takes place, previous learning necessary for each lesson, and an explanation of the student activity that takes place in each lesson. Next, I provided a more detailed description of the science content and the language content that is related to the lesson or activity. Then, I gave an explanation of why the lesson is considered to be inquiry-based and a description of the model of IBL that is being used in the lesson. Lastly, I used the Goal, Access prior knowledge, New information, Apply knowledge, and Generalization (GANAG) lesson plan format used by my school to present the lesson plan for each of the lessons in the unit. Many of the lessons are intended to cover multiple science and language standards and last over more than one class period. As such, each of the GANAG lesson plans will include multiple objectives and outcomes.

Lesson overview. This section includes a description of the intention of the lesson. I described the unit in which the lesson takes place, any prior learning necessary for each lesson, and an explanation of the student activity that takes place in each lesson. Also included in this section will be the estimated number of classes over which the lesson takes place.

Science overview. Each lesson was based on a science content goal that is set by the Minnesota state science standards. In this section of the lesson presentations, I gave a brief explanation of the science content that is being taught in the lesson. As some of the lessons provided multiple uses within science content, I provided a discussion of the way that the lesson is intended in the context of this capstone.

Language overview. Each of the lessons included a language goal that is set by the WIDA language standards that have been connected to the course by the district. I presented an overview of the language objectives for each lesson and why those objectives fit with the lesson content. I included an explanation of the importance of these objectives as they relate to future science learning.

Inquiry-based learning explanation. Each of the lessons was based on inquiry learning models that have been discussed in the previous chapters of this capstone. In this section of the lesson presentations, I provided a discussion on how the lesson was inquiry-based and the model or models that were implemented in the lesson.

GANAG lesson plan format. Each lesson was completely written out using the GANAG model, which is a lesson planning model that has been developed by Pollack (2009) and is used in my school. GANAG is an acronym that stands for Goal, Access prior knowledge, New information, Apply knowledge, and Generalization. Each component of this model is briefly described below. Included in each description are questions that teachers should ask themselves as they reflect on the planning of a lesson. These questions were proposed by Daniel Hanrahan from the Rubicon School District in Rubicon, WI, as cited by Pollock and Ford (2009).

Goal. This is the part of the plan that includes the learning objectives for the lesson. It can be thought of as the purpose of the lesson. Questions used to frame this part of the lesson include: What will you be teaching? What is it that you want students to know, be like, or be able to do? How will you communicate the learning goal to the students?

Access prior knowledge. This section of the lesson causes students to think back to previous experience that will be connected to the current lesson. Prior knowledge might be previous lessons (What did we do yesterday?) or to experience that students have had outside of school (Think of a time when you…). Teachers should consider the question: What will you do to access students' prior knowledge? In IBL models, students might begin to generate questions related to the goal during this part of the lesson.

New information. This is the part of the lesson when teachers present the content related to the lesson objective. In IBL models, this is when students might develop a procedure related to the goal or the questions that they have developed. Otherwise, teachers might present some type of information that requires students to develop new schemas to perpetuate learning. Questions to consider during this part of planning include: What is the new, important declarative and procedural knowledge that students must learn to achieve the goal of the lesson?

Apply knowledge. During the application phase, students use the new information to gain experience with the new content. How will you present the new information multiple times, using a variety of input modes? In IBL structures, students use the procedures they developed to work with the new information. At this point, teachers need to consider the chunking of the new information: How will you divide and teach the content to engage students' brains?

Generalization. This section includes communicating the information in new ways or explaining and/or analyzing the outcomes of the procedures. How will students summarize the learning in relation to the lesson goal? In IBL, how will they develop their own generalizations? An important question for teacher to consider at this point is: How will you know that they know?

These lessons are presented in the format shown in the organizer that is in Appendix 1. Each of these lessons will be displayed in the subsequent appendices.

Outcomes

Through my work on this capstone, I designed a unit for a content-based physical science course for ELLs that will answer the question: How can inquiry-based learning be used in a content-based physical science class for English language learners? I chose to write this curriculum for the content-based course because I feel that this area of education is in need of development in my district. The district that I work for has a high population of ELL students, and this population is growing, not only in my district, but in districts across the nation. CBI offers educators an effective model for instructing ELLs both in language and in content.

I chose to focus these lessons on the implementation of IBL for several reasons. State and national science standards include the concept of inquiry itself as a skill that all students should practice throughout science courses because it lies at the heart of the scientific process as used in the real world; current models of CBI science courses do not emphasize this enough. Furthermore, IBL provides students with authentic experiences in the content of science. Experience is a key factor in the acquisition of second language. The intent of this capstone is to show how IBL can be used in CBI science courses to make richer the language learning components of the class.

Lastly, effective IBL models engage students because the questions, procedures, and explanations are student-generated. This engagement is especially crucial for ELLs because the stakes of school are much higher for them—they must learn both content and language at a faster pace than that of their peers if they are to successfully compete for college admissions and future jobs. Moreover, student engagement in learning needs to be among the highest considerations of teachers at all levels of education.

<u>Human Subject Approval</u>

I have received approval for my capstone study from the Human Subject Research Committee of the Hamline University School of Education as well as from the district in which I teach. My capstone committee consisted of primary advisor Susan Manikowski as well as secondary advisor, Richard Matthes and peer reviewer Carrie Petroske. Susan is a staff member at Hamline University. Both Richard and Carrie are teachers in the same district in which I work; Richard teaches science, and Carrie teaches English.

<u>Chapter Summary</u>

In this chapter, I have described the setting in which I work as well as the students for whom this unit of study is intended. I have laid out how my lessons were designed and how they were aligned to state science standards and language standards. I presented an overview through a graphic organizer of how the science and language material fit into each lesson. I also included a description and example of the lesson design format (GANAG) that I used for each lesson. Finally, I explained potential outcomes of this curriculum.

In Chapter 4, I will present seven lessons that provide an example of how IBL can be used in a content-based physical science course for ELLs. These lessons will serve as models for teachers who hope to implement IBL methods in CBI science courses and will provide an answer to my research question: How can inquiry-based learning be used in a content-based physical science class for English language learners?

CHAPTER FOUR

Curriculum Design

Introduction

The methods used in inquiry-based learning (IBL) and content-based instruction (CBI) in science show a great deal of overlap. Inquiry-based learning is a technique that is widely used in science curricula and forms the basis of state and national science standards. Content-based instruction is a design that involves the concurrent instruction of content objectives and language objectives. The use of IBL in classes for English language learners (ELLs) presents an overlap of pedagogy, known as the Synergistic Effect. Effective methods used in IBL are closely related to the effective teaching practices of ELL instruction. These overlaps provide a firm rationale for the use of IBL in the ELL classroom. This connection was discussed in previous chapters in greater detail, and it is the basis of the lessons that are presented in this chapter. This chapter will include seven lessons that show how different models of IBL can be incorporated into a physical science curriculum to take advantage of the overlap of pedagogies of IBL and CBI instruction. These lessons will answer the question of this capstone: How can inquiry-based learning be used in a content-based physical science class for English language learners?

In the first section of this chapter, I will discuss the format in which each lesson will be presented, which includes a lesson overview, a science overview, a language overview, explanation of the IBL method and the actual lesson plan format for each lesson. In the second section of this chapter, I will present the lessons themselves, and the lesson plans will be presented in the following appendices.

Presentation of the Lessons

In this section I will discuss the format in which I present each lesson. To begin, I give an overview of the lesson as a whole, including a description of the unit in which the lesson takes place, prior learning necessary for each lesson, and an explanation of the student activity that takes place in each lesson. Next, I give a more detailed description of the science content and the language content that is related to the lesson or activity. Then, I provide an explanation of how the lesson is inquiry-based and a description of the model of IBL that is being used in the lesson. Lastly, I use the Goal, Access prior knowledge, New information, Apply knowledge, and Generalization (GANAG) lesson plan format used by my school to present the lesson plan for each of the lessons in the unit. Many of the lessons are intended to cover multiple science and language standards and last over more than one class period. As such, most of the GANAG lesson plans include multiple objectives and outcomes.

Lesson overview. This section includes a description of the main components of the lesson, including the student activities that take place during the lesson. I describe the unit in which the lesson takes place, any previous learning necessary for each lesson, and an explanation of the student activity that takes place in each lesson. Also included in this section is the estimated number of classes over which the lesson takes place.

Science overview. Each lesson is based on one or several science content goals that are set by the Minnesota state science standards. In this section of the lesson presentations, I provide a brief explanation of the science content that is taught in the lesson. As some of the lessons may provide multiple possibilities in which to teach science content, I provide a discussion of the way that the lesson is intended in the context of this capstone.

Language overview. Each of the lessons includes a language goal that is set by the WIDA language standards that have been connected to the course by the district. I present an overview of the language objectives for each lesson and why those objectives fit with the lesson content. I also include an explanation of the importance of these objectives as they relate to future science learning.

Inquiry-based learning explanation. Each of the lessons is based on IBL models that have been discussed in the previous chapters of this capstone. A variety of methods of IBL exist due to differing the level of instruction given to students in the areas of questions, procedures, and explanations. These different levels have led to the development of several models of IBL: confirmation inquiry, structured inquiry, guided inquiry, and open inquiry. In this section of the lesson presentations, I provide a explanation of how the lesson is inquiry-based and a description of the model or models that are being implemented in the lesson.

GANAG lesson plan format. Each lesson is completely written out using the GANAG model, which is a lesson-planning model that has been developed by Pollack (2009) and is used in my school. GANAG is an acronym that stands for Goal, Access prior knowledge, New information, Apply knowledge, and Generalization. A more in-depth discussion of these lesson components can be found in chapter three of this capstone.

Lessons

Inquiry-based learning can and should play a key role in a CBI physical science course for ELLs. Effective methods used in IBL are closely related to the effective teaching practices of ELL instruction. These overlaps provide a strong rationale for the use of IBL in the ELL classroom. This connection was discussed in previous chapters in greater detail, and it is the basis of the lessons that are presented in the sections below.

Lesson 1: Speed of a Toy Car

Lesson overview. In this lesson, students use small electronic toy cars to explore the concept of speed. This lesson takes place near the beginning of a unit on motion and forces. Students will use the skills of measuring distance and time to connect those concepts to the idea of speed as a rate of distance over time. Students will learn the use of the term "per" as it relates to the idea of mixed units. Also, students will practice the use of comparative and superlative language when comparing the motion of different cars. If students have mastered measuring distance and time, then this lesson can take place over two to three class periods. If this lesson serves as an introduction to those skills, more time would be required for students to carry out the necessary data collection. This lesson is a good example of CBI in action. The science concept, while it is not overly demanding, supports the language concepts, and thus becomes more rigorous. Furthermore, as students explore the science concept, speed, they are immediately required to put into use the language concepts and are forced to link the language with experience.

Science overview. Students are given the question, "What is the speed of the toy car?" Students are guided toward the equation for speed (speed = distance/time), using the common knowledge of speed limits and car speedometers. After discussing these ideas, students are given the task of finding the speed of the toy car. They need to develop a procedure to collect the necessary information using a meter stick to measure distance and a stopwatch to measure time. After collecting their data, students need to use their findings to report the speed of the toy car. They use this finding to generalize the concept and calculation of speed by finding different distances and times the car would take to travel in a given situation.

Language overview. In this lesson students will practice two separate language skills. The first is the definition and the use of the term "per" as it applies to mixed units in science. The examples that are used in this lesson are the different units that are used for speed. For example, "meters per second" as represented by "m/s" is used to show how the term "per" relates the values for distance and time through division. Students use the phrase "for each" to replace the term "per" to turn a speed value into a sentence. As an example, the speed value "5 m/s" would turn into "the car travels 5 meters for each second." As students move through any science curriculum, they will encounter many more mixed unit terms. Being able to create meaning from these terms leads to a deeper understanding of the relationship that is communicated through the terms. This lesson offers a good chance to introduce students to this concept in a way that is more concrete and visible than in other situations.

The second language skill that is addressed is the use of comparative and superlative language for regular adjectives. The two adjectives that are used to introduce this concept are "fast" and "slow." Obviously these two terms relate to speed and students need these to communicate about the activity. The use of "fast" and "slow" in this lesson give students an opportunity to practice turning these regular adjectives into comparative (-er than…) and superlative (-est) because they do not require a root change. This concept can be built upon in later lessons, because it is an important skill needed to communicate in the sciences. Often, the goal of science is to compare and contrast different factors to draw conclusions, so this skill is used throughout a student's education.

Inquiry-based learning explanation. This lesson uses guided inquiry as students are given the question but must work to develop a procedure to collect data and work to connect that data to the question. Students are also responsible for communicating their results on how their data is related to the question.

GANAG lesson plan. See Appendix 2.

Lesson 2: Inertia

Lesson overview. In this lesson students will explore how mass and inertia are related. Students are provided with a variety of balls of different sizes, materials, and densities. They are also provided with several pieces of equipment to move the balls – ramps, elastic bands, swinging mallet, etc. The students must develop a procedure to test the relationship between mass and inertia. Students practice the language surrounding the skill of making a claim and supporting that claim with evidence. Because students need time to develop a procedure, the activity of this lesson may require several class periods to complete. At first, students may need some time to "play around" with the materials in the lab to get an idea of how they can set the balls into motion. After this, students should be directed to develop a more specific approach to supporting the claims. Students should already know how to measure mass, and they should be familiar with the concept of inertia. This lesson could also be used to introduce those two concepts. In that case, more time would be needed to instruct students throughout this lesson on how those ideas are related to the activity. Key points of guidance in this lesson include helping students see that the more massive objects are more difficult to start moving, but once those objects are moving, they are more difficult to stop.

Science overview. Students are given three claims and they must use the data they collect as evidence to support those claims.

1. Mass and inertia are related.
2. Objects that have more mass have more inertia.
3. Objects that have less mass have less inertia.

Students then go about collecting evidence that supports these claims. Students will develop methods to test how the balls with different masses show different resistance to changes in motion. Students then communicate their findings by making a claim with evidence from the lab. For example:

Claim – "The bowling ball has the most inertia."

Evidence – “After the bowling ball was rolled down the ramp, it took the longest distance to stop.”

Language overview. For this lesson, students will be introduced to the terms “claim” and “evidence” and they will demonstrate their understanding of claim and evidence by making connections to the lab data that they collect. This skill is crucial to communication in science as the process of science seeks to makes claims about the world and support those claims with evidence collected through scientific investigation. This lesson gives students the opportunity to collect data and practice using that data as evidence to support claims.

Inquiry-based learning explanation. Depending on the starting point for students, this lesson can either use a guided inquiry approach or a confirmation inquiry approach. A guided inquiry approach is used for this lesson if the students have not been introduced to the concepts of mass and inertia in advance. In this scenario, the teacher provides the question, “How are mass and inertia related?” The students must design the procedures and collect the evidence that explains the relationship to the question. This lesson may be more effective if the confirmation approach is used. This model would provide students with the question, “How can you show that mass and inertia are related?” Students would know the result in advance (more mass means more inertia), so more focus can be placed on finding the evidence that supports this claim.

GANAG lesson plan. See Appendix 3.

Lesson 3: Force Carts

Lesson overview. In this lesson students will explore how force, mass and acceleration are related. The activity is used in a unit on Newton's Laws, as it is used to teach Newton's second law, which relates force, mass, and acceleration. Students should have an understanding of mass and acceleration. The lesson can be used to introduce or reinforce the concept of force. The activity includes using a hanging weight attached to a string that is attached to cart. Student can change the force pulling the cart by changing the mass of the hanging weight. Students can also change the mass of the cart by adding weights to the cart. This lesson will introduce students to the terms "increase" and "decrease," and it gives them the opportunity to use these terms as they communicate the findings of the activity. The lab portion of this lesson takes place over two to three class periods, with one to two additional class periods to have students report on their conclusions.

Science overview. Students will use a hanging weight that is attached to a cart by a string to pull the cart across a table. They measure the time it takes for the cart to travel one meter. Students can change the pulling force by changing the mass of the hanging weight by adding or removing metal masses. Students are asked to measure the time it take the cart to travel one meter for five different pulling forces. They repeat this procedure two more times after more mass is added to the cart.

The apparatus used in this activity allows students to explore the idea that as the force put on an object increases, the acceleration of that object increases. Also, students should see that as the mass of an object increases, it takes more force to accelerate the object. Depending on the standards and depth of the course, this activity can lead into a lesson on the use of the equation *force=mass x acceleration*.

Language Overview. Students are introduced to the verbs "increase" and "decrease." Many concepts in science require describing how a factor changes in response to some other factor that changes. Being able to use scientific terms to describe a variable or quantity getting larger or smaller is crucial to an effective ability to communicate in science.

Inquiry-based learning explanation. This lesson uses a structured inquiry model because the question and the procedure are given to the students. They will use the hands-on activity to gather evidence to support an explanation about the relationship between force, mass and acceleration. They communicate this understanding by making claims and using the data from the activity as evidence.

GANAG lesson plan. See Appendix 4.

Lesson 4: The Trebuchet

Lesson overview. This is a hands-on, engineering-based lesson in which students will build a device that allows them to launch a projectile at targets, similar to the popular mobile device game, Angry Birds. This lesson takes place in a unit on forms of energy, specifically the transformation of potential energy into kinetic energy.

Students design and build a working trebuchet that uses the potential energy of a falling counterweight to launch beanbags at a target. Students must first construct the trebuchet using the provided materials (ex. PVC tubing, connectors, tape, cardboard) that meets the specifications of the project (ex. size, trigger mechanism). Then they have several class periods to investigate what factors control the distance and flight path of the beanbags. After several days of testing and recording their findings, students participate in the “Angry Birds Challenge.” Each launch challenge provides students with different obstacles: different distances, throwing over a bar, throwing under an archway, throwing through a hoop, knocking down items of varying weight, etc. Since they have a limited number of attempts at each challenge, they need to rely on their test results to be efficient at hitting the target at each obstacle.

Students then provide an account of what adjustments they tried in order to complete each challenge. Students are taught the language surrounding the concept of cause and effect and the use of “if…then…” statements to communicate this relationship.

Depending on the supports given to students in the actual construction of the trebuchet, this lesson can last for up to two weeks. Students will require at least three to four class periods to construct the trebuchet and an additional two to three class periods for testing the trebuchet. The challenge day can happen in just one class period depending on class size and space availability.

Science overview. The trebuchet that students construct demonstrates how the potential energy of a falling counterweight is transformed into kinetic energy to launch beanbags. During the testing phase of this lesson, students begin to make connections between the concepts of potential energy and kinetic energy because they see that adjusting the mass of the counterweight is one way in which to change the speed and distance that the beanbag travels. During the testing phase, students are required to record their findings on how changing the potential energy, among other factors, can be used to control the launch. Because they have a limited number of attempts at each challenge, they need to use on their test results to efficiently at hit the target at each obstacle. This lesson offers an opportunity for students to calculate the potential and kinetic energy involved in the launches, so depending on the class, this would be an appropriate addition to this lesson.

Language overview. This lesson gives students the chance to practice using cause and effect language, which is an extremely important skill for the communication of scientific ideas. Much of scientific communication is based on relaying how some factor affected some outcome, as this is the basis of the scientific method. During this lesson, students will be making changes to their trebuchet and observing the outcome: How did the flight of the beanbag change when we increase the mass of the counterweight? Students will be instructed to observe and record those changes and outcomes, and then communicate those findings using "If…then…" statements. For example, "If we increase the mass of the counterweight, then the beanbag goes farther."

Inquiry-based learning explanation. From a big-picture perspective, this lesson is guided inquiry because the teacher provides the question. In this case, the question is the engineering challenge. However, within each day of the activity, students are working in an open inquiry model. They are responsible for developing their own questions, procedures and conclusions based on the individual needs of their project.

GANAG lesson plan. See Appendix 5.

Lesson 5: Building a Circuit

<u>Lesson overview.</u> This is a hands-on lesson in which students construct simple electric circuits to see how stored chemical energy in a battery can be transformed into other forms of energy. This lesson takes place near the end of a unit on forms of energy, so students have an understanding of how energy can exist in different forms and how it changes from one form to another. The activity presented in this lesson will reinforce those concepts for students and give them the opportunity to see how simple devices can transform energy. The new information in this lesson, both in regards to the science and the language, is related to scientific modeling and the use of diagrams and symbols to communicate ideas in science. This lesson usually takes place over five to six class periods. The first two classes are used for the students to build and draw the challenge circuits. The next day consists of teaching the electric diagram symbols and process and having students convert their drawings into circuit diagrams. Days four and five consist of showing how the computer modeling program works and giving students work time. The last day involves generalizing the modeling and diagramming and giving students a chance to build a circuit from a diagram. More time would be required based on the needs of students for finding a diagram or model and creating a short presentation that describes the model and how it is useful.

<u>Science overview.</u> The materials that are available to students are batteries, wires with alligator clip ends, light bulbs and sockets, electric motors, and simple switches. Students are given a list of challenges that requires them to construct different circuits. After they construct each circuit, students are required to draw what the circuit looks like, being sure to show the connections that were needed to make a working

circuit that met the challenge. As the complexity of the circuits increases, students realize that drawing a picture of the circuit is a cumbersome and an ineffective way of communicating their findings. Thus, students also work on the concept of a scientific model during this lesson. After completing the circuit building exercise, students are shown how electric circuits are modeled using electric diagram symbols. After this guidance they are instructed to convert their circuit drawings into circuit diagrams using the proper symbols. Lastly, they use an online modeling program to diagram their electric circuits to show how computers can be useful in communicating scientific models.

Language overview. In this lesson, students are introduced to the vocabulary related to scientific modeling: model, diagram, symbol. They practice using these vocabulary words as they turn their real-life circuits into electric circuit diagrams on paper and on the computer. Students are instructed on the strengths and weaknesses of different models, and they discuss how models are useful. The language skills that are required to talk and write about scientific models are crucial to future language development not only within the context of science classes, but in all fields of study.

Inquiry-based learning explanation. The first part of this lesson is guided inquiry. The teacher gives students the questions, and students are required to develop a procedure that answers those questions. In this case, the questions are the different circuit challenges. Most students have not had much of an opportunity to explore how simple electric circuits work, so most of the initial learning takes place by trial and error. As students complete more circuits, they build on the knowledge that they acquire.

GANAG lesson plan. See Appendix 6.

Lesson 6: Layered Liquids

Lesson overview. The Layered Liquids lesson could take place in a unit on properties of matter or it could be used during a unit on the particle theory of matter. In both cases, this lesson can either act as an introduction to the concept of density or as a part in a group of lessons that focus on buoyancy, to show how the density of objects causes them to float or sink. If this lesson is serving as an introduction to density, the teacher can introduce the idea that density represents the amount of matter in a certain amount of space and connect this to the amount of sugar in each of the solutions, as explained below. If the students have already been introduced to the topic of density, then students should make this connection on their own or with some guidance from the teacher. The science portion of this lesson takes one to two class periods to complete. The language component in this lesson has students focus on adjectives and phrases that describe relative location of objects, and can take an additional one to two class periods to teach.

Science overview. In this lesson, students will follow a procedure to make several different sugar solutions with different concentrations of sugar. Each solution is made by using the same amount of water to dissolve different masses of sugar. Then, each solution is turned a different color using food coloring. Students use droppers to carefully add the colored sugar solutions to a small test tube, attempting to create a stack of layered liquids. (A variation on this activity is to give students directions on which color to add to each solution, and then have students attempt to layer the liquids in order of the colors of a rainbow.) As students attempt to layer the liquids, they will begin to formulate questions about what they are seeing. (Why did the red solution sink to the bottom? Why did the blue solution mix with the yellow solution? Why did the yellow solution stay on the top?) They should start to make connections between the layers of colors and the concentrations of the solution. These concepts are generalized by giving the students a picture of a test tube with colored layers, and students must correctly mix solutions and put them in a test tube to match the given test tube. To incorporate the language goals into this generalization, a description of the tube, rather than a picture, could be used so students must show they understand the language of relative location as well.

Language overview. Students practice adjectives and prepositional phrases that describe location including: above, below, on the top, on the bottom. In order to describe their observations, students will need to reference the order in which the liquids are layered. In doing this, students will have an opportunity to practice that language skill within the context of the science activity. Again, this is a great example of CBI, as the language goal and the science goal are interdependent. Depending on the language levels of the students, this activity could act as an introduction to location adjectives, as one part of a series of lessons that covers location adjectives or as a review of the concepts for practice.

Inquiry-based learning explanation. This is a modified open-inquiry model because students are only provided with a procedure. The teacher does not provide a specific question related to the procedure. The students must develop a question based on their observations of the activity and then use their observations as evidence to support their conclusions to their questions.

GANAG lesson plan. See Appendix 7.

Lesson 7: Iodine Clock

Lesson overview. The Iodine Clock is the versatile activity that provides teachers with a variety of avenues to pique students' interest in chemical changes, reaction kinetics, and the scientific method. It offers students a great opportunity to experience the concepts of variables in a scientific experiment. For the purpose of this capstone, its use will focus on the scientific method component, since the course science standards do not include the chemistry topics that could be discussed.

This lesson can be carried out in the context that students have already been introduced to the concept of a controlled experiment and have been guided through one experience of controlling variables in an experiment. Students should have previously been introduced to the concepts of independent and dependent variables as well. If this is the case, then this activity can act as an assessment of their ability to correctly identify and control these variables. This activity could also be used as an introduction to all these concepts. If this is the case, then more time should be taken during the inquiry process to help students correctly identify and control the variables that are involved in the reaction. For the lesson presented in this capstone, it will be assumed that students have not been exposed to the concepts, and the lesson is acting as an introduction for students to begin to understand the concepts of a controlled experiment.

As mentioned above, this experiment can be used in a variety of ways, one of which being to introduce or reinforce the concepts of chemical reactions and chemical changes. While it might be useful for students to have had an introduction to these concepts, it is not crucial. A simple explanation of how the reaction works should provide students with enough knowledge to be able to manipulate the variables in this experiment. More focus could be placed on the chemistry of the activity if the teacher feels that it is necessary or if it works within the context of the class. For this course, and the inquiry lessons being presented in this capstone, it is not assumed that students have a deep understanding of the chemical processes taking place in the reaction. Rather, the focus is on the students' abilities to develop a controlled experiment that uses the reaction as a vehicle for this to take place.

This lesson is as versatile in amount of required class time as it is in science connections. Depending on the amount of guidance given to students and the intentions of the lesson, this activity can be completed in as few as three class periods or as many as ten, depending on the extent to which students are expected to investigate the reaction. Usually, one day of introduction, four to five days of testing, and one day of completing the challenge is sufficient to effectively work through this activity without reaching the limit of student interest.

Science overview. The Iodine Clock involves three solutions that can easily be made from simple drug store chemicals. Solution A is made by dissolving Vitamin C tablets in water. Solution B is an iodine tincture made by diluting concentrated iodine solution. Solution C is made by diluted liquid starch in water and adding 3%

hydrogen peroxide solution. The reaction is carried out by first mixing Solution A and B together. Students will see that the solution changes color. Then, Solution C is added. At first, no change is seen. After several minutes, the solution changes colors again to a dark purple/black color. The time between the color changes is what creates the “clock” effect that is used as the dependent variable in the experiment.

For this lesson, students are given the overarching question, “How can you control the timing of the Iodine Clock?” Students are informed that in several days, they will be given a certain time interval goal within some given time parameters. For example, the teacher could say the time interval goal will be a 30-second interval some time between one and seven minutes. Students need to determine how they can control the reaction to change colors at 30-second intervals between one and seven minutes. If they carry out a reaction that lasts longer than seven minutes or less than one minute, they know that those reaction conditions will not meet the challenge.

During the days leading up to the challenge, students must develop tests to determine how they can control the clock. It is during this time that students are practicing the concepts of controlling variables to determine the effect of an independent variable on the dependent variable. Support can be given to the students by helping them identify the dependent variable as the time it takes for the iodine clock to change color. Further, teachers can help students brainstorm what variables might have an effect on the timing of the changes. Depending on students’ background knowledge, they may only attempt to control the clock by manipulating the amounts of each solution used. They might have other ideas about how to control the clock that may include changing the temperatures of the solutions or adding something to the solutions or removing components of the solutions. Because of the inquiry nature of this lesson, students should be allowed to test whatever factors they come up with, provided they are safe and practical within the context of the classroom. Teachers assess the students' abilities to correctly design an experiment that tests only one variable at a time while controlling the other variables to determine the effect on the time of the clock.

Language overview. This lesson will focus on the concept of writing a scientific question for a controlled experiment. Each variable they choose to test gives students the opportunity to write a scientific question that relates the independent variable to the dependent variable. In scientific writing and communication, a formulaic approach is used to communicate the intent and findings of scientific research. Writing a scientific question in the form of, "How does [the independent variable] affect [the dependent variable]?" is an inroad to this type of writing process. This is a skill that students will use again and again in future science classes.

Inquiry-based learning explanation. Students are given the question, "How can you control the Iodine Clock?" This lesson is open inquiry, because within the context of the overarching question, students develop their own questions as they design the experiment. Students need to develop their own procedure, which is how the inquiry of determining the variables that affect how the reaction takes place. After collecting data from their procedures, students need to determine how that evidence answers the questions they asked.

GANAG lesson plan. See Appendix 8.

Chapter Summary

In this chapter, I presented seven lessons that show how IBL can be used in a CBI physical science course for ELLs. Each of the lessons included science and language goals that were based on state standards for the course. The lessons showed how, through the use of different IBL methods and models, language can be taught concurrently with science to provide a rich and rigorous course. Each lesson is intended for use in different units throughout the course, so the information presented in this chapter can help a teacher who would like to modify an existing physical science curriculum to include IBL lessons over the course of an entire school year. The lessons presented in this chapter provide examples that answer the question of this capstone: How can inquiry-based learning be used in a content-based physical science class for English language learners?

In Chapter 5 I will briefly revisit the literature on IBL methods and CBI. I will provide a discussion of the connection between these concepts and how that connection influenced my curriculum design. I will also discuss my findings regarding the design of the lessons presented in Chapter 4. Finally I will talk about recommendations that I would make to others who are interested in using IBL methods in a CBI physical science course for ELLs.

CHAPTER FIVE

Conclusion

Introduction

I have been teaching science for seven years in a large city in the upper Midwest. Throughout my career in teaching, I have been involved with the education of English language learners (ELLs) in the area of science. In both my district and our nation, there is an increasing demand to educate a growing population of ELLs. Because of this demand, there is growing popularity in the use of content-based instruction (CBI) courses that include the concurrent teaching of both content standards and language standards. In my experience, these classes have lacked both the ability to pique student interest and the inclusion of inquiry-based learning (IBL) methods. The purpose of this capstone was to investigate and develop methods that can be used to build a rich and rigorous science course for ELLs by using the concept of inquiry-based learning. This led me to my research question: How can inquiry-based learning be used in a content-based physical science class for English language learners?

In this capstone I began by telling the story of my journey to teaching, specifically my interest and involvement in teaching ELL science and the use of IBL in the CBI science classroom. I then reviewed the literature on IBL and CBI and their interconnectedness before describing how the lessons I developed would be presented. Finally, I presented my lessons. In this chapter I will discuss how this process has affected me as a teacher and as a learner. I will do this by returning to the review of literature and discussing a few topics that were highlighted throughout my experience of developing these lessons. Following this I will discuss the implications of my work before describing some limitations of my curriculum design. Finally, I will suggest several recommendations for any teachers who may be interested in using IBL in a CBI science class for ELLs.

A Return to the Review of Literature

As I designed the lessons that are presented in this capstone, I found myself returning to many of the topics that were discussed in the review of literature. Individually, both the concepts of IBL and CBI are broad and encompass many aspects of education. When these two ideas are brought together, several themes emerge. The themes include the importance of experience in learning language, the ability of CBI to provide that experience in science, the variety models of IBL, and the interconnectedness of IBL and CBI in science or the Synergistic Effect. These themes formed the foundation of my thinking as I designed my lessons, and in this section I will provide a brief discussion of each of these themes.

Language and experience: Task-based language learning. When implementing experience-based language learning solutions to the growing challenge of ELL education, it is crucial to include consideration of theories of language acquisition. The idea of language acquisition through experience, or task-based language learning, has led to the development of several theories that describe the ways in which task and experience can promote the development of second language acquisition. These theories, which are developed more in Chapter 3, present arguments that support the coupling of language teaching to direct experience and tasks through which the language is taught. These theories form the basis of CBI and rationalize its use in language instruction classrooms. The lessons that are presented in this capstone exemplify this theory, as they provide students with both individual and shared experiences in science content that enhance learning of the English language.

Content-based instruction use in science. The learning of science content inherently includes the need to learn new language, both for native English speakers as well as English language learners (ELLs). The lessons presented in this capstone show how these language goals can be taught with the science content and experience as the backdrop for the language learning that takes place. Quality science instruction connects concepts to previous experiences, whether in or out of school. In order to support ELLs' language acquisition teachers must deliberately connect content experience to language in science. These lessons showcase this concept by presenting language goals concurrently with science goals. Furthermore, they show how learning language through content instruction can take place. Through CBI, teachers are able to provide ELLs with firsthand encounters and experiences with science content. Within the CBI context, these lessons provide multiple avenues through which to create these experiences: current news or popular culture, cooperative work, discrepant events, hands-on activities, and laboratory investigations.

Different models of inquiry-based learning. Inquiry-based learning is at the core of the ideas on which state and national science standards are based. Students generate questions, procedures, and explanations based on their areas of interest. While IBL has played a large role in the development of science curricula for decades, inquiry does not refer to a single type of lesson but rather a range of approaches that form a continuum. Researchers have described this continuum as levels that differ in the amount of specific instructions given to students. More information on these levels can be found in Chapter Three. These different levels of IBL have been categorized in different models. The major models that have been described by researchers are confirmation inquiry, structured inquiry, guided inquiry, and open inquiry (Bunterm, 2014; Miranda, 2012; Bianchi & Bell, 2008). The lessons that I presented in Chapter Four utilize all of these different models as well as blending some of the models together to form effective activities that develop students' inquiry abilities.

<u>The Synergistic Effect</u>. While the traditional model of science education of ELLs has tended to avoid inquiry approaches, researchers have argued that the integration of inquiry science and language acquisition enhances learning in both domains (Stoddard, 2002). Bergman (2011) argues that there is a mutual benefit to language acquisition and science content learning because there is a pedagogical overlap of IBL and ELL instruction. He defines this overlap as the "Synergistic Effect" (Bergman, 2011). More details pertaining to Bergman's theory can be found in Chapter Three. This theory provides the primary rationale for the development of the lessons that I presented in this capstone. I strongly feel that the overlap between the pedagogies of science instruction through inquiry and language instruction does exist, and it enhances the ability of teachers to effectively teach both science and language. Thus, it is crucial to develop lessons that take into account this overlap. In this capstone, I have presented seven

lessons that show how an ELL physical science course can capitalize on the mutual benefit of language instruction and science instruction through inquiry.

Summary. In the section above, I discussed several key themes that emerged from my review of literature that I took into account as I designed the lessons presented in Chapter 4. These themes, among other concepts, formed a rationalization for the development of the lessons. The lessons show how IBL can be used in a physical science course for ELLs.

Implications

This capstone focused on the development of high-quality science lessons that are intended for use in ELL classrooms. The growing population of non-native English speakers in our country has led to a growing demand to provide a high-quality education for those students. The lessons that are presented in this capstone provide an example of the type of thinking that is required to produce an effective educational process for these students. The students are not the only stakeholders in this process. The outcomes and realizations of our students affect all member of our society. The more we demand of our students, and thus the system that educates them, the more expectation we can have for a brighter future. Ultimately, the onus is on the teachers who are planning these courses to utilize effective, engaging methods, such as IBL and CBI, to promote the achievement of all of our students.

Limitations

While it is my hope that any teacher who has been tasked with teaching science to a population of ELLs can utilize the lessons that I have presented in this capstone, it is possible that there may be limitations to what a teacher can do in this capacity. In this section, I will discuss several constraints that may limit a teacher's ability to implement the lessons that I have presented, which include very limited language skills, logistical limitations, and limited content background.

Limited language skills. Because of differences among school districts, there exist varying models of ELL instruction. Some of the models may place students with very limited English abilities into a CBI class for science. The lessons that have been presented in this capstone are intended for students who are a Level 2 English proficiency based on WIDA English proficiency standards. Some districts may include Level 1 ELL students in their CBI science courses while others may not have effective placement or testing procedures which lead to misplacement of students. In either situation, some of the content presented in the lessons, whether science or language content, may not be accessible to all ELL students in these classes. Hopefully, teachers in these situations can modify the lessons or use them as a launching point for developing lessons that include IBL models.

Logistical limitations. Many of the lessons that I presented in Chapter Four require the use of science apparatus, materials, or space that may simple not be available to all teachers who are planning CBI science courses for ELLs. Unfortunately, the organization of many schools does not place a high priority on introductory classes, especially ELL classes, to have access to adequate science facilities and materials. Most of the lessons that I presented could be modified to fit a variety of settings, but as they are presented, limited access to adequate facilities could present a constraint for some teachers wishing to implement these lessons.

Limited content background. Because my school district assigns a science credit for the ELL physical science course that I teach, as the teacher of the course, I am required to hold a science license. This may not be the case for all CBI science teachers who are teaching ELLs. Different models that give content credit for a CBI class may include having a ELL licensed teacher obtain a certification in the content area. Others may simply have an ELL teacher teaching the CBI science course without giving a science credit for the course. In both of these situations, the teacher may find that their science knowledge may limit their ability to teach using the IBL models that I have presented. Because IBL is based on open questioning for students, ideas and concepts may arise from this open questioning that goes beyond teacher's content comfort zone. I would encourage these teachers to think of IBL on a continuum and implement lessons that include some aspects of inquiry, rather than avoid all IBL models as a rule.

Summary. The lessons that I presented in Chapter 4 are intended for Level 2 ELLs, and are based on a science content licensed teacher instructing in rooms that are intended for science classes. Because of the wide variety of ways that CBI is implemented in different districts, some of these assumptions may provide limitations for the direct application of the lessons. Regardless of the reasons that limit a teacher from utilizing these lessons, they still form a basis for thinking of how IBL can look in a CBI science course, and I hope that they provide strong models that other teachers can modify for effective use.

Recommendations for Future Work

During the writing of this capstone I learned a great deal about the theories that support the use of IBL models in CBI science courses. I developed seven lessons that are based on these theories. For others that are also interested in working on similar lessons I recommend that future projects look at developing lessons that fit into other content areas of science. There is a growing demand to provide CBI models for higher-level science courses, such as biology, chemistry, and physics. Furthermore, I would encourage any future projects to look at how IBL models could be implemented in other content areas besides science. ELL students deserve high-quality, rigorous coursework in any content class they take, and I strongly feel that IBL theories can be the basis for many of these classes.

Communicating the Lessons

It is my hope that the lessons that I have presented in this capstone will be readily available to any teacher who wishes to implement IBL lessons in a science classroom. I plan to continue to work on these strategies in my classroom and present and refine these lessons. I will share this information with the science department and the ELL department at my school. Also, I plan to post these lessons on the teachers' resources section of my district's curriculum website.

Chapter Summary

In chapter five, I described how the process of building the lessons in the capstone has affected me as a teacher and as a learner. I returned to my review of literature and discussed several topics that were highlighted throughout my experience of developing these lessons. I then discussed the implications of my work before describing some limitations of the lessons that I presented. Finally, I will suggested several recommendations for any teachers who may be interested in using IBL in a CBI science class for ELLs, as well as described several ways in which I will communicate my work in this process.

The process of writing the capstone and developing the lessons I presented has given me a better understanding of the theories that promote learning through inquiry and its use in a content-based science class for ELLs. I was able to broaden my array of teaching tools that will help me better develop science lessons for both content-based language classes and regular content classes as well. I was able to conduct research and apply that knowledge in a way is useful to me in my current teaching position. Furthermore, I was able to connect this project to my own personal background and interest in the inquiry learning process and my global view of education. The research I conducted and the lessons that I presented answer my research question: How can inquiry-based learning be used in a content-based physical science class for English language learners?

APPENDIX 1: GANAG Lesson Plan Format

	Science Content	Language Content
Goal Set the learning goal/benchmark or objective	**Science Standards** applying to that lesson	**Language Standards** applying to that lesson
	Science Guiding Question(s)	**Language Guiding Question(s)**
	Science Measurable Objective	**Language Measurable Objective**
Access Access students' prior knowledge building engagement through establishing immediate relevancy; a "hook" that is a short introduction to the lesson	Possible **Instructional Strategies** to Try**:** • Review of previous lesson • Pair and Share • Brainstorming • Quick Write • Verbal check-in of prior knowledge • Visual to access prior knowledge	
New **Information** Acquire new information – declarative and/or procedural	Possible **Instructional Strategies** to Try**:** • Modeling and direct instruction • Student discussions • Academic feedback to students • Non-fiction writing, vocabulary and reading strategies to develop understanding of new information • Inquiry based questions and activities	
Apply Apply a thinking skill or use knowledge in a new situation. Opportunity for feedback provided	Possible **Instructional Strategies** to Try**:** • Guided Practice • Independent and group work • Student demonstration of learning objective • Student-to-student discussions using accountable talk • Ongoing checks for understanding • Continuous academic feedback to the students	
Generalize Generalize what has been taught. How will the teacher know if students met the measurable objective?	Possible **Means of Assessments** to Try: • Oral or written summary of lesson • Exit slip or quick write • Pair and share • Peer and individual review of work • Class discussion of topic • Cornell notes check	

Adapted from SPPS alignment of lessons to goal, access, new information, apply and generalize (GANAG). GANAG comes from the book, *Improving Student Learning One Principal at a Time* by Jane E. Pollock and Sharon M. Ford.

APPENDIX 2: GANAG Lesson Plan for Lesson 1 – Speed of a Toy Car

	Science Content	Language Content
Goal Set the learning goal/benchmark or objective	**Science Standards** Measure and calculate the speed of an object that is traveling in a straight line. Develop possible solutions to an engineering problem and evaluate them using conceptual, physical and mathematical models to determine the extent to which the solutions meet the design specifications.	**Language Standards** English language learners communicate for social and instructional purposes within the school setting. English language learners communicate information, ideas, and concepts necessary for academic success in the content of science.
	Science Guiding Question(s) What is the speed of a toy car?	**Language Guiding Question(s)** What does "per" mean? How can we compare the speeds of different toy cars?
	Science Measurable Objectives Students can identify the information that is needed to calculate speed (distance and time). Students can design a procedure that allows them to gather the information that is needed to calculate speed (distance and time).	**Language Measurable Objectives** Students can explain how the term "per" relates two values. Students can write comparative and superlative statements using regular adjectives.

Access Access students' prior knowledge building engagement through establishing immediate relevancy; a "hook" that is a short introduction to the lesson	Allow time for students to play with the different toy cars. Have a short discussion about what is different about the motion of each of them. Use car speedometer images to begin the discussion of how speed units work ("mph" – What does that mean?) Use different speed limit signs to discuss how the motion would look at different speeds.	Use car speedometer images to begin the discussion of how speed units work ("mph" – What does that mean?) Use different speed limit signs to discuss how the motion would look at different speeds (fast vs. slow).
New Information Acquire new information – declarative and/or procedural	Speed = distance/time "Per" is a term that links two measurement units through division. In order to calculate the speed of a moving object, you must know the distance traveled in a certain amount of time.	"Per" is a term that links two measurement units in a way that means "for each." Comparative regular adjectives (add –er ending, use of "than") are used when comparing two people or things. Superlative regular adjectives (add –est) are used when comparing one person or thing with every other member of their group.
Apply Apply a thinking skill or use knowledge in a new situation. Opportunity for feedback provided	Students design and carry out a procedure to collect distances and times for a toy car.	Students turn speed values into sentences by replacing "per" with "for each." Students compare the speeds of their toy car with other groups. They write comparative statements using "faster" and "slower" and superlative statements using "fastest" and "slowest."

Generalize Generalize what has been taught. How will the teacher know if students met the measurable objective?	Students are given a data table with distances and times for several other cars. They calculate the speed. Students determine how far their toy car could travel in a certain amount of time. (ex. 1 hour) Students determine how much time it would take their toy car to travel a certain distance. (ex. 1 kilometer)	Students use other modes of transportations to compare speeds. Students complete an exercise using other regular adjectives to demonstrate understanding of comparative and superlative adjectives.

APPENDIX 3: GANAG Lesson Plan for Lesson 2 – Inertia

	Science Content	Language Content
Goal Set the learning goal/benchmark or objective	**Science Standards** Recognize that inertia is the property of an object that causes it to resist changes in motion. Formulate a testable hypothesis, design and conduct an experiment to test the hypothesis, analyze the data, consider alternative explanations and draw conclusions supported by evidence from the investigation.	**Language Standards** English language learners communicate for social and instructional purposes within the school setting. English language learners communicate information, ideas, and concepts necessary for academic success in the content of science.
	Science Guiding Question(s) How are mass and inertia related? How can we show that objects that have more mass have more inertia?	**Language Guiding Question(s)** How can we use evidence to support a claim?
	Science Measurable Objectives Students can describe the relationship between the mass of an object and the inertia of the object.	**Language Measurable Objectives** Students can identify claims and the evidence that supports those claims. Students can use evidence to support claims that they make.

Access Access students' prior knowledge building engagement through establishing immediate relevancy; a "hook" that is a short introduction to the lesson	(Students have already been introduced to the concepts of inertia and mass. Access this prior knowledge by connecting to whatever lesson was used to teach those concepts) Use clips of the World's Strongest Man competitions to show very massive objects that have a lot of inertia are hard to move.	Use a clip from a crime show (CSI) to introduce the term "evidence" and discuss why evidence is important (to show that something – claim – is true).
New Information Acquire new information – declarative and/or procedural	Objects that have more mass have more inertia. Therefore, it is harder to change their motion. In science, we can use observations (data) as evidence to support our claims.	Claim – What do you think? Evidence – Why do you think that? How do you know?
Apply Apply a thinking skill or use knowledge in a new situation. Opportunity for feedback provided	Students design a lab that tests the question "How are mass and inertia related? Students use the evidence they collect to support the claims.	Students turn the data collected into sentences that can be used as evidence statements. Students complete an exercise in which they match the evidence statements they have written to claim statements on the board.
Generalize Generalize what has been taught. How will the teacher know if students met the measurable objective?	Students are asked to predict how three balls of different mass would behave using the same tests from the lab. They turn these predictions into claim statements. Students are given several evidence statements about three different balls. They are asked to predict the mass (inertia) based on those statements.	Students write sentences that describe the evidence that they would use to support the claims (predictions) they made.

APPENDIX 4: GANAG Lesson Plan for Lesson 3 – Force Carts

	Science Content	Language Content
Goal Set the learning goal/benchmark or objective	**<u>Science Standards</u>** Recognize that inertia is the property of an object that causes it to resist changes in motion. Formulate a testable hypothesis, design and conduct an experiment to test the hypothesis, analyze the data, consider alternative explanations and *draw conclusions supported by evidence from the investigation.*	**<u>Language Standards</u>** English language learners communicate for social and instructional purposes within the school setting. English language learners communicate information, ideas, and concepts necessary for academic success in the content of science.
	<u>Science Guiding Question(s)</u> How are mass and inertia related?	**<u>Language Guiding Question(s)</u>** How do we use the verbs "increase" and "decrease?"
	<u>Science Measurable Objectives</u> Students can describe the relationship between mass and inertia	**<u>Language Measurable Objectives</u>** Students can conjugate the verbs "increase" and "decrease" in both the present tense and past tense.
Access Access students' prior knowledge building engagement through establishing immediate relevancy; a "hook" that is a short introduction to the lesson	Use a wagon and cart and have students describe what they have to do to move the wagon and cart (pull or push). Ask students what they would have to do to make the wagon or cart move faster. Have students add weight to wagon and cart and describe how the force they needed to use to move the wagon or cart changed.	Brainstorm examples of relationships in which one factor increasing or decreasing causes another factor to increase or decrease. *Example: Increasing your years of education increases your average salary.* Represent these relationships with up arrows for increase and down arrows for decrease.

N **ew Information** Acquire new information – declarative and/or procedural	As force increases, acceleration increases. As the mass of the object increases, the acceleration of the object decreases. Force, mass, and acceleration are related by the equation F=ma, Newton's Second Law of Motion. *Students would explore this mathematical relationship in subsequent lessons. This lesson would be used to access prior knowledge for that lesson.*	Increase means to get larger or go up in numerical value. Decrease means to get smaller or go down in numerical value. Conjugate the forms of the verbs in present and past tense.
Apply Apply a thinking skill or use knowledge in a new situation. Opportunity for feedback provided	Students carry out the procedure using the cart and hanging weight to explore the relationship between force, mass, and acceleration.	Students use arrows to visually represent the concepts of increase and decrease for the relationship among force, mass and acceleration. Students fill in Cloze sentences with the correct form (both conceptually and grammatically) of the verbs "increase" and "decrease."

Generalize Generalize what has been taught. How will the teacher know if students met the measurable objective?	Using a cart mass that is different from any in the lab, students are asked to determine what mass of hanging weight causes the cart to travel the meter in a given time interval (2-3 seconds). Using a hanging mass that is different from any in the lab, students are asked to determine what mass is needed on the cart to cause the cart to travel the meter in a given time interval (2-3 seconds). Students summarize the relationship between force, mass, and acceleration using their own sentences that include the correct grammar for "increase" and "decrease."	Students summarize the relationship between force, mass, and acceleration using their own sentences that include the correct grammar for "increase" and "decrease." Students may use the Cloze sentences for support, but they should change the relationship to show understanding.

APPENDIX 5: GANAG Lesson Plan for Lesson 4 – The Trebuchet

	Science Content	Language Content
Goal Set the learning goal/benchmark or objective	**Science Standards** Calculate and explain the energy, work and power involved in energy transfers in a mechanical system. Develop possible solutions to an engineering problem and evaluate them using conceptual, physical and mathematical models to determine the extent to which the solutions meet the design specifications.	**Language Standards** English language learners communicate for social and instructional purposes within the school setting. English language learners communicate information, ideas, and concepts necessary for academic success in the content of science.
	Science Guiding Question(s) How does a trebuchet demonstrate energy transformation? How does changing the mass of the trebuchet's counterweight affect the flight of the beanbag? What trebuchet design allows you to complete as many challenges as possible?	**Language Guiding Question(s)** How do we use If..then… statements to communicate cause and effect?

	Science Measurable Objectives	**Language Measurable Objectives**
	Students can describe how a trebuchet shows the transformation of potential energy into kinetic energy. Students can explain how increasing or decreasing the mass of the trebuchet's counterweight affects the flight of the beanbag using the concept of conservation of energy. Students can work within the parameters to design a trebuchet that meets the challenges.	Students can use "If…then…" statements to communicate how changes to their trebuchet (counterweight, launch angle, arm length) affected the flight of the beanbag.
Access Access students' prior knowledge building engagement through establishing immediate relevancy; a "hook" that is a short introduction to the lesson	Use interest in Angry Birds and other similar games to generate interest in how a projectile can be controlled to hit a target. Use "NOVA: Secrets of a Lost Time – Medieval Siege" video to teach/model the concept of a trebuchet and show the engineering challenges involved with building a working trebuchet.	Brainstorm different cause and effect relationships within the school (eg. When marked tardy to class, the school calls home). Use examples in the NOVA video to show the cause and effect relationship.

New Information Acquire new information – declarative and/or procedural	Kinetic energy is the energy of a moving object. Potential energy is energy that is stored, in this case, by the position of an object. Energy can change forms (transforms). Potential energy is stored in the position of the counterweight. As the counterweight falls, the energy transforms to kinetic energy that is transferred to the beanbag. The total amount of energy in a system does not change. Energy is conserved. A greater amount of mass of the counterweight means that there is more potential energy that is available to transform into kinetic energy, meaning the beanbag can travel faster/farther. The trebuchet design must be strong enough and work efficiently enough to transform the energy in an effective manner.	"If…then…" statements are used in science to show a cause and effect relationship: If [cause] then [effect].

Apply Apply a thinking skill or use knowledge in a new situation. Opportunity for feedback provided	Students design and build a trebuchet that meets the specifications and that can effectively attempt each of the challenges. Students test different factors, including different masses of counterweight that affect the flight of the beanbag and record their findings.	Use If You Give a Mouse a Cookie children's book to show simple statements of "if…then…" and identify the cause and effect in each scenario. Each day of testing, students are responsible for recording at least 3 "if…then..." statements that show what they observed during their tests. They need to identify the cause and the effect for each statement.
Generalize Generalize what has been taught. How will the teacher know if students met the measurable objective?	Students participate in the Angry Birds Challenge, in which they have limited attempts to successfully hit the target of each challenge. The challenges present students with obstacles that require them to demonstrate their understanding of how the trebuchet transforms potential energy into kinetic energy. Students describe the challenges that they faced in the design and construction of the trebuchet. Students use cause and effect statements to show their understanding of how the trebuchet demonstrates conservation of energy and energy transformation.	Students use cause and effect statements to show their understanding of how the trebuchet demonstrates conservation of energy and energy transformation.

APPENDIX 6: GANAG Lesson Plan for Lesson 5 – Electric Circuits

<table>
<tr><th></th><th>Science Content</th><th>Language Content</th></tr>
<tr><td rowspan="3">Goal

Set the learning goal/benchmark or objective</td><td><u>Science Standards</u>

Calculate and explain the energy, work and power involved in energy transfers in a mechanical system.

Select and use appropriate numeric, symbolic, pictorial, or graphical representation to communicate scientific ideas, procedures and experimental results.</td><td><u>Language Standards</u>

English language learners communicate for social and instructional purposes within the school setting.

English language learners communicate information, ideas, and concepts necessary for academic success in the content of science.</td></tr>
<tr><td><u>Science Guiding Question(s)</u>

How does an electric circuit demonstrate energy transformation?

Why are models useful in science?</td><td><u>Language Guiding Question(s)</u>

What is a scientific model?</td></tr>
<tr><td><u>Science Measurable Objectives</u>

Students can explain how an electric circuit shows the transformation of energy.

Students can describe how a model is useful for communicating in science.</td><td><u>Language Measurable Objectives</u>

Students can use the terms model, diagram, and symbol as they relate to scientific modeling as subjects and as verbs (to model, to diagram, to symbolize).</td></tr>
</table>

Access Access students' prior knowledge building engagement through establishing immediate relevancy; a "hook" that is a short introduction to the lesson	Review the different forms of energy and energy transformations with some simple electronic devices. Explain how a battery transforms stored chemical energy into electrical energy. Access the idea of models by asking students to draw a map of the room. Show that drawing every detail is not important.	Access the idea of models by asking students to draw a map of the room. Show that drawing every detail is not important. Access the idea of symbols by discussing symbols of different countries. Students will bring up the concepts of flags, national animals, colors, etc. Show how these symbols represent the ideas of the country without actually having to show the entire idea.
New Information Acquire new information – declarative and/or procedural	A circuit is a closed loop of electrical conductors that allows electricity to flow from one side a battery to the other. A scientific model or diagram is a simplified way to show the important parts of a more complicated system. Symbols are simple representations of items or ideas that allow for more clear and efficient ways to communicate the item or idea.	Define *model, diagram,* and *symbol* as they relate to scientific modeling. Conjugate the verbs for *model, diagram,* and *symbolize* as they relate to scientific modeling
Apply Apply a thinking skill or use knowledge in a new situation. Opportunity for feedback provided	Students build several circuits of increasing complexity that allow simple devices to work. Students convert an actual drawing of the circuit into an electrical diagram that uses electric symbols for the different parts of the circuit. Students use a online electrical modeling program to model the electric circuits.	Students use the terms to describe the models that the built.

G **eneralize** Generalize what has been taught. How will the teacher know if students met the measurable objective?	Students are given a circuit diagram for a new circuit and they must construct the real-life version of that circuit. Students choose a different scientific model (either related or unrelated to electricity) and make a short presentation to the class about how that model simplifies the actual idea that it is representing.	Students choose a different scientific model (either related or unrelated to electricity) and make a short presentation to the class using proper grammar related to the verbs and nouns.

APPENDIX 7: GANAG Lesson Plan for Lesson 6 – Layered Liquids

	Science Content	Language Content
Goal Set the learning goal/benchmark or objective	**<u>Science Standards</u>** Explain density, dissolving, compression, diffusion and thermal expansion using the particle model of matter.	**<u>Language Standards</u>** English language learners communicate for social and instructional purposes within the school setting. English language learners communicate information, ideas, and concepts necessary for academic success in the content of science.
	<u>Science Guiding Question(s)</u> Why do things float or sink?	**<u>Language Guiding Question(s)</u>** What words do we use to describe the location of a person or thing?
	<u>Science Measurable Objectives</u> Students can define *density*. Students can explain how the density of a substance relates to its tendency to float or sink.	**<u>Language Measurable Objectives</u>** Students can use locations adjectives and phrases to describe the different layering of liquids in the activity.
Access Access students' prior knowledge building engagement through establishing immediate relevancy; a "hook" that is a short introduction to the lesson	Show a picture/video of an oil spill and discuss the issues related to density (or floating and sinking). *Ex. In what ways is it bad that oil floats on water? In what ways is it good that oil floats on water? What if oil was more dense than water?*	Use oil spill images to introduce location adjectives related to this activity. (*The oil floats <u>on top of</u> the water. The water is <u>below</u> the oil.*)

New Information Acquire new information – declarative and/or procedural	Density is a measure of how much mass is in a certain volume (*how much stuff in a certain amount of space*.) Less dense liquids float on more dense liquids.	Location adjectives and prepositions: above, below, on the top, on the bottom.
Apply Apply a thinking skill or use knowledge in a new situation. Opportunity for feedback provided	Students use the concept of density to explain why the liquids form the layers that they see.	Students use location adjectives and prepositions to describe the layers of liquids that they observe in the activity.
Generalize Generalize what has been taught. How will the teacher know if students met the measurable objective?	Students are given a picture of a test tube with layered liquids in a certain order of colors. They must write directions that tell how the solutions were made. (Match the densest solution with the solution on the bottom and so on.) Students can provide an explanation of why oil floats on water and include the concept of density.	Students are given a picture of a test tube with layered liquids in a certain order of colors. Students must write directions that include location adjectives that explain the procedure needed to make a test tube with that order of colors.

APPENDIX 8: GANAG Lesson Plan for Lesson 7 – Iodine Clock

	Science Content	Language Content
Goal Set the learning goal/benchmark or objective	**Science Standards** Formulate a testable hypothesis, design and conduct an experiment to test the hypothesis, analyze the data, consider alternative explanations and draw conclusions supported by evidence from the investigation. Develop possible solutions to an engineering problem and evaluate them using conceptual, physical and mathematical models to determine the extent to which the solutions meet the design specifications.	**Language Standards** English language learners communicate for social and instructional purposes within the school setting. English language learners communicate information, ideas, and concepts necessary for academic success in the content of science.
	Science Guiding Question(s) How can you control the timing of the iodine clock?	**Language Guiding Question(s)** How do we write a scientific question?
	Science Measurable Objectives Students can identify independent and dependent variables. Students can design an experiment in which they test only one variable and control the other variables. Students can carry out a procedure that correctly controls the iodine clock to turn colors in a given time interval.	**Language Measurable Objectives** Students can write a scientific question in the form of "How does [the independent variable] affect [the dependent variable]?"

Access Access students' prior knowledge building engagement through establishing immediate relevancy; a "hook" that is a short introduction to the lesson	Discuss past experiences in the engineering process. Introduce the idea of chemical engineering – using chemistry to solve a problem. Demonstrate the iodine clock. Discuss the chemicals that are involved and address students questions related to the demonstration. Brainstorm ways in which the clock can be controlled.	Use several different examples of questions with some being scientific questions and other not. Discuss the differences in those questions and the intentions of the questioner.
New **Information** Acquire new information – declarative and/or procedural	*Variables* are the factors that can be changed in an experiment that have an effect on the outcome of the experiment. In order to determine the effect of a variable, all the other variables must be kept the same. These are the *control variables*. The *independent variable* is the factor that the experimenter changes. The *dependent variable* is the factor that the experimenter is measuring. It may or may not be affected by the independent variable.	A scientific question connects an independent variable to a dependent variable. A scientific question must be testable, not an opinion. Basic scientific questions are written in the form, "How does [the independent variable] affect [the dependent variable]?"

Apply Apply a thinking skill or use knowledge in a new situation. Opportunity for feedback provided	Students develop a procedure that tests one variable that could affect the timing of the Iodine Clock. They must control the other variables by keeping them constant. They measure the dependent variable by timing the color change of the reaction.	For each procedure that students develop, they must present to the teacher the question they are testing in the form, "How does [the independent variable] affect [the dependent variable]?" The question must be written correctly in order for students to obtain the materials they need to carry out the procedure.
Generalize Generalize what has been taught. How will the teacher know if students met the measurable objective?	Students are given other lab procedures and must identify the variables in those procedures. Students are given other lab procedures and must critique the procedures for the effectiveness of testing only one variable while controlling the other variables.	Students are given other lab procedures and must write a scientific question for those procedures.

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