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Development of a 5th Grade Ecology Unit about the Sagebrush Ecosystem Using Next Generation Science Standards, Place Based Education Principles, and English Language Learner Best Practices

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Development of a 5th Grade Ecology Unit about the Sagebrush Ecosystem Using Next Generation Science Standards, Place Based Education Principles, and English Language Learner Best Practices

By

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Plan B Project

Submitted in partial fulfillment of the requirements for the degree of Masters in Science in Natural Science Education in the Science and Mathematics Teaching Center at the University of Wyoming 2016

Laramie, Wyoming

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Abstract

When developing science curriculum that incorporates the Next Generation Science Standards (NGSS), research has shown that it is important for teachers to adapt their units in order to provide context and meaning to what their students are learning. Place based education (PBE) is one way to provide this meaning within context (Sobel, 2004). NGSS can provide all students an equal opportunity to become scientifically literate (Lee, Miller, & Januszyk, 2014). Since 1995, the population of English Language Learners (ELLs) in the United States has increased by 57% (Maxwell 2009). ELLs across the nation share the same common challenge of learning English while also meeting the academic content demands (Bautista & Castaneda, 2011). There has been no research conducted to date that incorporates these three elements into curriculum development. Therefore, this research project aimed to look at how a science unit could be developed using PBE principles, NGSS, and ELL best practices in order to (a) increase understanding of scientific concepts related to the sagebrush ecosystem for 5th grade students; (b) incorporate diverse instructional strategies, intended to enhance the student’s connection to place and (c) include strategies and best practices for ELLs in order to meet these students’ language needs without sacrificing content. The project concluded that principles of PBE and ELLs can serve as guides for developing science curriculum that aligns with NGSS. The combination of these three frameworks help to create an equal-opportunity, learning environment through creating common experiences, holding all students to the same standards, and providing needed language scaffolding and modifications without sacrificing content.
This work is dedicated to Linda Wellings, who first inspired me to connect all children to the natural world
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Chapter 1

Introduction

Background and Rationale

The process of using the local community and environment as a starting point to teach concepts across all subjects of curriculum such as language arts, mathematics, social studies and science has been shown to increase student achievement through more meaningful and applied learning (Sobel, 2004). This educational approach is commonly referred to as Place-Based Education (PBE). PBE is an educational approach that uses all aspects of the local environment, including local cultural and historical information and the natural and built environment as the integrating context for learning (Sobel, 2004). This type of learning emphasizes hands-on, real world experiences that access students’ prior knowledge about a particular place. This helps students to find and make meaningful connections in order for them to reach a deeper understanding of what they are learning. PBE encourages students to develop stronger ties to their community, enhance appreciation for science and the natural world, and creates a heightened commitment to serving as active, contributing citizens (Sobel, 2004). Programs that have successfully engaged students through PBE have been found to create supportive and collaborative communities of learners that use learning activities relevant to students’ lives (Smith and Sobel, 2010). Through the incorporation and implementation of a variety of place based principles, there is a higher potential to improve numerous education outcomes. Such PBE principles include experiential and hands-on learning, connections to peers and local community,
bringing in community-based experts, using local settings, involving real-world challenges, making learning student-centered, and involving inquiry in the classroom (Meichtry and Smith, 2007). One of the primary strengths of PBE is that it can be effective in a variety of settings, which make it possible for instructors to adapt the principles to the unique characteristics and standards of particular places. (Smith, 2002). Therefore, there is the potential to incorporate PBE in many different classroom settings.

As a result of the No Child Left Behind Act (2001), there has been a lack of focus on curriculum development and teaching practices. Instead, teachers find themselves trying to meet mandated district, state and national standards and were being held accountable for meeting standardized testing scores by the same entities. In elementary schools across the country there has been an overall lack of science instruction, which has been an unintended consequence of these legislative mandates. From the later 1980s to the early 2000s, K-12 science teachers and the large science education community have witnessed an era of standards-based reform (Bybee, 2013). Included in these reform efforts was the recent development of the Next Generation Science Standards (NGSS). Over the past three decades, science reform efforts have been focused on inquiry-based learning as being the most effective way of connecting students to science (Houseal et al, 2014). The NGSS, developed from 2010 to 2013, include this type of learning as they strive to prepare scientifically literate students for college and careers. NGSS require that students have a deeper understanding of a smaller number of concepts than previous science standards, which tended to have more emphasis on shallower, factual knowledge (Pruitt, 2014). NGSS aims to address science literacy for citizenship among all students by holding them to a higher standard and providing the necessary resources need to achieve these goals. (Stage et al., 2013).
NGSS are based on recent research in science education that tells us that “Students learn science by actively engaging in the practices of science, including conducting investigations; sharing ideas with peers; specialized ways of talking and writing; mechanical, mathematical, and computer-based modeling; and development of representations and phenomena” (NRC, 2007, p. 251). A key idea behind creating the NGSS was “to develop clear, comprehensive, and challenging goals for student learning” (Bybee, 2013, p. 34). Based on this research the Framework for K-12 Science Education (NRC, 2012) proposed a three-dimensional learning framework, and the NGSS were developed based on this. The three dimensions identified that would help students reach scientific literacy include: Disciplinary Core Ideas (DCIs), Crosscutting Concepts (CCCs), and Scientific and Engineering Practices (SEPs). Historically, K-12 instruction has encouraged students to memorize lots of facts about “science”, claiming that these facts would make them literate in science. However, research now shows that engaging in the practices that are used by scientists and engineers play a critical role in comprehension. When science is taught as a process of inquiry and explanation, students are able to think beyond the subject matter to form a deeper, more meaningful understanding of how they can apply science to their everyday life (NSTA, 2014). The NGSS framework provides a structure that teachers can use to help students be an active participant in “doing” science rather than only learning about science (Houseal, 2015).

In addition to science standard reform, there are a rising number of students in the United States whose first language is not English. Since 1995, the population of English Language Learners (ELLs) in the United States has increased by 57% (Maxwell 2009). Though ELLs come from many different backgrounds, they share the common challenge of learning English while meeting the academic content demands (Bautista & Castaneda, 2011).
Despite the growing number of ELLs in the classroom, K-12 teachers have little training to help them meet the needs of these students. In a nationwide study, 42% of participating school teachers in the U.S. reported that there were ELLs in their classrooms, and only 13% reported that they had received specific training to assist them in teaching their linguistically and culturally diverse students (Castaneda & Bautista, 2011). It is important to understand that the content expectations for ELLs should not be different than their mainstream, English-speaking peers. Regardless of a student’s English language proficiency level, it should only be the language that is modified. As these students move through proficiency levels it is crucial that language be scaffold in order to maximize their language development (Bautista & Castaneda, 2011). With the goal of providing all learners with the same high-quality, academically challenging content to both native English speakers and those learning English, many schools are implementing sheltered instruction to help serve the needs of ELLs in mainstream content-area classes (Hansen-Thomas, 2008). Sheltered instruction includes: (a) the use of cooperative learning activities within heterogeneous groups; (b) a focus on academic language as well as content vocabulary; (c) judicious use of ELLs first language; (d) use of hands-on and experiential activities that use authentic materials, demonstrations, and modeling; (e) use of student’s background or prior knowledge; and (f) explicit teaching and implementation of learning strategies (Hansen-Thomas, 2008). These strategies help teachers reach these students without having them be removed from the classroom.

According to Teaching English to Speakers of Other Languages (TESOL), effective education of ELLs, requires that curriculum be adapted and modified to meet the needs of these students so that they have equal opportunities to grasp the content being taught (Kumaravadivelu, 2006). Historically, it has been assumed that language development and
content development can only happen independently. However, there is increasing evidence that 
the development of language is best achieved when taught within the context of content learning 
(Bautista & Castaneda, 2011). There are several key planning strategies for teachers who have 
ELLs in their classroom. First, know ELLs language proficiency levels. Next, align content and 
language objective within a lesson plan, create a link between background knowledge and 
science instruction, and provide opportunities for comprehensible input, which is language that 
students can understand, but is just beyond their current level of competence. Finally, provide 
opportunities for interaction with peers and teachers, and use performance-based assessments 
(Bautista & Castaneda, 2011). Through the implementation of these lesson planning strategies 
and practices, teachers will have the opportunity to accomplish the language goals of their ELL 
students without jeopardizing the content objectives being taught.

**Problem Statement**

As the number of ELLs in a classroom continues to increase, it is crucial that teachers 
begain adjusting and scaffolding their lesson plans and overall curriculum to meet the needs of 
these students. This will help teachers offer the same high-quality, academically challenging, and 
meaningful learning to all students within their classroom. The application of PBE principles in 
developing curriculum units using the NGSS can support and increase understanding of these 
science standards through relevant and meaningful application. Although, many of these place 
based principles align with strategies and best practices used for ELL students, there is hardly 
any literature that incorporates all three; NGSS, PBE, and ELL. Therefore, it is not well 
understood how teachers can effectively incorporate place based principles, the NGSS, and ELL
best practices in order to create curricular units that can successfully reach all students within their classroom.

**Purpose and Research Questions**

This study aims to develop a 5th grade ecology unit based on the Wyoming sagebrush ecosystem. The unit seeks to incorporate the principles of PBE, the three dimensions of NGSS, current research being conducted by UW faculty on the sagebrush ecosystem, and strategies and best practices of ELL. The goal is to create a science unit that is meaningful and accessible to all students within the 5th grade classroom. The project aims to answer the following questions:

How can the research literatures on PBE principles, ELL strategies and best practices, and NGSS guide the development of a 5th grade unit about the sagebrush ecosystem?

Further, how can this unit:

- Guide the connection of students to a local ecosystem through local scientists?
- Align with appropriate 5th grade Next Generation Science Standards focused on ecology and ecosystems?
- Include appropriate ELL strategies and best practices in order to make this science unit available for all students in a given classroom?
Chapter 2

Review of Literature

Overview

This research study is important in the larger context of strengthening curriculum design and enhancing educational practices. Through exploring the principles of Place-based education (PBE), strategies and best practices used for English language learners (ELLs) and the Next Generation Science Standards (NGSS), this research aims to increase science understanding and scientific literacy for students of all backgrounds. The development and modifications of curriculum to meet the needs of students learning English is crucial in our current context as the number of ELLs in public school classrooms continues to rise (Maxwell, 2009). The implementation of place-based principles into curriculum provide an opportunity for students to gain a deeper understanding of scientific content through the connections made to their local community or place. Paul D. Hurd (1998) stated, “Science education for all students is seen as curricula that can be lived and that students can relate to.” By incorporating the NGSS into curriculum, students will see an increase in achievement as they are engaged in quality science education through the three dimensions of NGSS: disciplinary core ideas, crosscutting concepts, and science and engineering practices (Pruitt, 2015).

This research involved the development of nine 75-90-minute science lessons for 5th grade students about the local sagebrush ecosystem of Wyoming. These lessons are intended to (a) increase understanding of scientific concepts related to the sagebrush ecosystem (b) incorporate diverse instructional strategies, to enhance the student’s connection to place while
making content more meaningful and (c) include strategies and best practices of ELLs in order to meet these students’ language needs without sacrificing content.

This literature review is organized into four main sections. The first section focuses on curriculum development. The second section focuses on science education reform and the development of NGSS. The third section focuses on PBE and its principles, and the final section focuses on strategies and best practices for ELLs. Each of these sections contains multiple related subtopics to provide historical and theoretical context for the subsequence sections of this paper. The research for this unit was steered with the intention to:

• Guide the connection of students to a local ecosystem through local scientists.
• Align with appropriate 5th grade NGSS focused on ecology and ecosystems.
• Include appropriate ELL strategies and best practices in order to make this science unit available for all students in a given classroom.

Educational database searches were the general methodology used for discovering literature and resources. Relevant studies were sought using database resources such as ERIC, Academic Search Premier, and Google Scholar. Recommended resources and relevant research was also sought from field experts and University of Wyoming faculty.

Curriculum Development

Backwards Design

When thinking about curriculum development it is important to first put emphasis on the specific learning outcome prior to the development of relevant activities. Lessons and units should be logically inferred from curricular goals versus common concepts and activities. Wiggins and McTighe (2005) refer to this way of thinking and developing curriculum as
Backwards Design. This type of design focuses on the “why” and “so what” questions which lead students towards understanding versus their ability to recite rote facts.

The book “Understanding by Design” by Wiggins and McTighe (2005), discusses what the “twin sins” of traditional design. One is the error of activity-oriented designs that are hands-on, but lack connection to a larger purpose or question. Students have fun, but the activity does not challenge them intellectually. The second is referred to as “coverage”, which occurs when teachers plow through a textbook filled with multiple concepts. There is little or no time for students to make connections among concepts, nor time to understand how these concepts fit into the larger picture. Backwards Design aims to mitigate these practices by asking teachers to provide a careful statement of desired results, which are the priority learning (Wiggins & McTighe, 2005, p. 17). Wiggins and McTighe state:

We must grasp the key idea that we are coaches of their ability to play the “game” of performing with understanding, not tellers of our understanding to them on the sidelines. (p. 17).

There are three stages of backwards design. Stage one identifies desired results. This includes the relevant goals the teacher wishes students to achieve. These are referred to as the transfer goals, since students will carry them into future endeavors. This stage also includes enduring understandings, which address understandings students will gain, and essential questions that students will be working to answer throughout the unit. Lastly, stage one includes the knowledge, understanding and skill level students successfully acquire after completing this unit. Stage two is an assessment evidence necessary to verify and validate to that students have achieved the desired learning results. Stage three is the learning plan in which the designer determines the specific instructional activities and experiences that will be most appropriate to
meet the outcome. Backwards Design can be applied to any content area and is used as a way of thinking rather than a template for all curriculum development (Wiggins & McTighe, 2005).

**5E Learning Cycle**

The 5E learning cycle is a research-based, instructional model that was developed in 1997 by Rodger Bybee and his colleagues at the Biological Science Curriculum Study (Bybee, 1997). This instructional model is based on the constructivist view of learning in which teachers identify students’ misconceptions and prior knowledge and then provide time for students to explore and investigate. Students then reconstruct their knowledge and understanding (Bybee, 1997). The model includes 5 stages: Engage, Explore, Explain, Elaborate, and Evaluate and can be seen below in Figure 1.


The Engage stage is meant to pique students’ interest and curiosity, elicit prior knowledge and identify any student misconceptions. The teacher is not instructing or explaining
in this stage. In the *Explore* stage, learners participate in self-designed or guided inquiry-based investigations. They are encouraged to engage in a scientific process, such as the *Science Circle* (see Figure 2). During this stage students are encouraged to work in groups where they can share and communicate with their peers. The role of the teacher during this stage is to act as a facilitator and provide open-ended questions for the students to think about and discuss.

![Science Circle Diagram](image)

*Figure 2. The science circle representing the eight steps of the scientific process performed when doing inquiry-based, scientific investigations. (Teton Science Schools, [http://www.tetonscience.org/index.cfm?id=school_youth_science](http://www.tetonscience.org/index.cfm?id=school_youth_science), 2015)*

In the *Explain* stage, learners take time to reflect on their learning from the Explore stage and communicate this with their teacher and peers. Once learners have built their own knowledge base through inquiry and have communicated this knowledge, the teacher steps in to help students grasp conceptual understanding by providing formal instruction, introducing and defining key vocabulary, and addressing any misconceptions that emerged in the *Engage* stage.
The *Elaborate* stage gives learners the opportunity to explore and expand their newly constructed knowledge. Students are given the chance to make connections to other related concepts and apply their understandings (Bybee, 1997; Nargund-Joshi & Bautista, 2016).

The *Evaluate* stage is traditionally placed at the end of the lesson, but as Figure 1 demonstrates, this model is intended to be a learning cycle rather than a linear progression. Evaluate is shown in the center because teachers should be constantly evaluating and assessing their students throughout the entire lesson (Keeley, 2008). The incorporation of Evaluation in all the other stages is important as it allows time for both students and teachers to reflect on how much learning and understanding has taken place (Nargund-Joshi & Bautista, 2016).

**Assessment**

Assessment is a crucial piece of curriculum development because it is how teachers evaluate whether or not students have gained the knowledge, understanding, and skills that they set out to teach (Wiggins & McTighe, 2005). Educators agree that assessment practices that are both relevant to the student and content being taught are an integral part of informing teaching and learning (Keeley, 2008). This leads to the idea that curriculum should include “assessment for learning instead of assessment of learning” (Black et al., 2003).

Three types of assessment that can be incorporated into curriculum are diagnostic assessment, formative assessment, and summative assessment. Diagnostic assessment is used to identify preconceptions, lines of reasoning, and learning difficulties among students. Formative assessment is used to inform instruction and provide feedback to students on their learning. Summative assessment is used to measure and document the extent to which students have achieved a learning target or desired goal of the unit (Keeley, 2008).
Science Education Reform and the NGSS

History of Science Education Reform in the United States

In order to adequately understand the development of the NGSS, it is essential to look back at the history of science education in the United States. In the first 150 years of U.S. history there were over forty education reform efforts (Hurd, 1991). Science education has been a topic of concern for an extensive period of time. There are several reasons for this concern: teaching and learning are challenging tasks; the United States has a highly decentralized education system, unlike many other countries that have national curriculum; curriculum varies from state to state and classroom to classroom; and science teachers often find themselves without the preparation and support they need to adequately teach science curriculum (NRC, 2008). When Thomas Jefferson was the vice-president in 1798, he noted that, “little practical science was being taught in the schools at any grade level. He viewed the sciences as keys to the treasure of nature…hands must be trained to use them wisely” (Hurd, 1997, p. 407).

Science education did not become a part of the United States’ school curriculum until the 19th century. DeBoer (2000) states this was due to the insistence of scientists. After the Sputnik, scientists aimed to change science education so that all learners could learn science and practice scientific skills the same way that professional scientists did (Yager, 2000). These reforms occurred in the late 1950s and 1960s. (Hurd, 1997). During this time textbooks were not questioned and were conceived as a way to determine what teachers should be teaching rather than a template to base lessons off of (Yager, 2000).

By the 1970’s most of these reforms in science education had faded. During this decade, many people started to blame science for the current political, societal, and environmental crises.
This led political leadership in Washington to re-think science education and they funded Project Synthesis, which proposed the following four major goals for modern science education:

(1) Science education should prepare individuals to utilize science for improving their own lives and for coping with an increasingly technological world, (2) science education should produce informed citizens that are prepared to responsibly deal with science-related societal issues, (3) science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests, and (4) science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs (Yager, 2000, p. 51).

National Science Education Standards (1996)

The year 1996 brought yet another major set of rules and visions to science education with the release of the National Science Education Standards by the National Research Council of the National Academy of Sciences. These standards were organized around four main goals. The four new goals include the expectations that students must:

(1) Experience the richness and excitement of knowing and understanding the natural world, (2) use appropriate scientific processes and principles in making personal decisions, (3) engage intelligently in public discourse and debate about matters of scientific and technological concern, and (4) increase their economic productivity through the use of knowledge, understanding, and skills of the scientifically literate person in their careers” (NRC, 1996, p. 13).
Through meeting these goals students would be considered scientifically literate (DeBoer, 2000). It was important to increase the number of scientifically literate citizens in order for them to deal with daily scientific and technological information and help the United States maintain a global competitive edge (DeBoer, 2000). These new standards differed from those of the 1960’s in that science was not cast in real-world contexts and experiences. This means students were not given real problems or current issues, or encouraged to let their curiosity guide their questions (Yager, 2000).

**No Child Left Behind Act (2001)**

In 2001, the George W. Bush administration and Congress passed the No Child Left Behind Act (NCLB), which was a reauthorization of the Elementary and Secondary Act of 1965. The act held states accountable for students’ academic achievement through the use of federal funds (Abedi, 2004). If states did not meet the federal requirements for student achievement the federal government had the right, by law, to withhold and decrease funds to the state. Due to a variety in state content standards, rigor of tests, and stringency of performance standards, the percentage of students who scored at or above the proficiency level varied greatly from state to state (Linn, Baker, & Betebenner, 2002). In the wake of NCLB, there has been an increase of pressure on test-scores. This has had a negative effect on ELLs as they are often below their native English-speaking peers. This has led to a push for educators to provide language scaffolding for these standardized tests. ELLs are being tested for both their content ability and language proficiency (Abedi, 2004).


In December 2006, a report was published from a 14-member committee of the National Research Council. This report was titled *Taking Science to School: Learning and Teaching*
Science in Grades K-8 (NRC, 2008). The report was a comprehensive review of the most recent research on teaching and learning from a variety of disciplines. Some of the disciplines included in this study include “cognitive science, developmental psychology, education research, the design of effective learning environments, the history and philosophy of science, and new interdisciplinary fields, such as neurobiology and sociocultural studies of the mind” (NRC, 2008, p. xiv). The findings in Taking Science to School were often difficult to implement in the classroom because teachers found a disconnect between the scientific concepts and scientific processes, skills and practices, which led to students not being able to grasp the overall goals the teachers had set forth (Duschl et. al., 2008). This led to the development of the book, Ready, Set Science! (Michaels, Shouse & Schweingruber, 2007). For the first time there was something that made this content available for science education practitioners who work with and support K-8 teachers (NRC, 2008). The primary purpose of Ready, Set, Science was not a “how-to” book but, rather a guide that brings some of the best research to science education practitioners (NRC, 2008).

Taking Science to School also laid the foundation for A Framework for K-12 Science Education (NRC, 2012) and the NGSS (Achieve, 2012). This body of research indicates that there should be an emphasis on student development of metacognitive skills. The research recommends that conceptual knowledge be built through the use of learning progressions with the idea that children have the capability to think abstractly from a young age and therefore teaching should encourage them to think and practice in this way (Duschl et. al., 2008). (NRC, 2008, p. 18-21).

The Framework represents the first step in the process of creating a new set of K-12 science standards (NRC, 2012), though it includes similar goals to the standards and guidelines that came before it. These goals include the need for science and engineering improvements in K-12 science education. (NRC, 2012). The Framework is designed to help create a common vision across science and engineering education. It focuses on students’ engagement in scientific and engineering practices, as well as application of crosscutting concepts. These are meant to help deepen students’ understanding of the core ideas in these fields (NRC, 2012).

There are several guiding principles that make up both structure and content of the Framework. These principles include the idea that children are natural born investigators. They have a focus on core ideas and practices with the intention to focus on quality over quantity. The guiding principles also include the idea that understanding develops over time and science and engineering require both knowledge and practice. It is also important to connect to students’ interests and experiences, and science education should promote equity (NRC, 2012).

There is a deeper focus on inquiry-based science in the Framework through the development of eight specific science and engineering practices that are intended to deepen students’ understanding of the core ideas through hand-on, meaningful practice and application (NGSS, Appendix D, p.5). There are seven crosscutting concepts included in the Framework: patterns; cause and effect; scale, proportion and quantity; systems and systems models; energy and matter; structures and function; and stability and change (NRC, 2012, p. 84). These concepts were chosen and included into the Framework in order to provide connections for students learning new disciplinary core ideas. They have been especially useful when teaching ELLs because they provide opportunities for students to make connections to prior knowledge and prior experiences (Michaels et al., 2007).
There are many expectations for teachers, including development of students’ disciplinary knowledge, upward social mobility, socialization into the local community and broader culture, and preparation for informed citizenship (NRC, 2012). This is why one crucial goal of the NGSS framework is to help ensure and evaluate educational equity. The committee believes that educational equity should be at the forefront of any efforts of educational improvement because scientific literacy should be promoted and made accessible among all people (NRC, 2012). This can be accomplished by building on students’ prior interest and identity, leveraging students’ cultural knowledge, and making diversity visible (NRC, 2012). These goals can help teachers reach their diverse students.

**Next Generation Science Standards (NGSS) (2013)**

The development of NGSS was led by 26 lead partner states and the nonprofit organization Achieve (Stage et. al., 2013). NGSS was developed to promote clear and comprehensible goals towards student learning, the alignment of curriculum, instruction, and assessments and was intended to boost student interest in science and science-based careers (Bybee, 2013). The NGSS is geared to guide students towards these goals using the three dimensions developed in the Framework. The three dimensions should not be taught in isolation. The core ideas should be connecting to crosscutting concepts and consistently explored through science and engineering practices (Houseal, 2015).

The three dimensions are:

1. Disciplinary Core Ideas
2. Cross Cutting Concepts
The core ideas include four scientific disciplines: life sciences, physical sciences, earth and space sciences, and engineering and technology (NGSS Lead States, 2013).

The cross cutting concepts are the concepts that connect the disciplinary core ideas together. Their purpose is to help students make these connections between the disciplinary core ideas and scientific and engineering practices in order to develop a deeper understanding of the four main disciplines (NGSS Lead States, 2013). The seven cross cutting concepts include:

1. Patterns,
2. Cause and Effect
3. Scale, Proportion, and Quantity
4. Systems and System Models
5. Energy and Matter
6. Structure and Function
7. Stability and Change

These cross cutting concepts also follow a progression through a student’s academic career and become more complex as a student’s knowledge increases. The third dimension of NGSS is scientific and engineering practices. The rationale behind including these practices in the framework is that, “by engaging in the practice of science, students can better understand how scientific knowledge develops, as well as engage their interest in the discipline of science. The National Research Council states that each of these practices should be addressed at each grade level, as they are accessible to any age in some form” (NRC, 2012, p. 42). There are eight scientific and engineering practices identified by NGSS:

1. Asking Questions and Defining Problems
2. Developing and Using Models
3. Planning and Carrying out Investigations
4. Analyzing and Interpreting Data
5. Using Mathematics and Computational Thinking
6. Constructing Explanations and Designing Solutions
7. Engaging in Argument and Evidence
8. Obtaining, Evaluating, and Communicating Information

Figure 4, below, is a visual representation of the three-dimensional learning in understanding the Framework and the NGSS (Houseal, 2015).

Figure 3. A model of the three dimensions of science learning that focuses on evaluating curriculum to meet the goal of having all three dimensions meet (Houseal, 2015).

This visual model is intended to help educators, school district personnel, and critical stakeholders have a better understanding of this three-dimensional learning of science through a model that explains the interaction that occurs among the three dimensions and the intersection
of all three, which is where we ultimately want to be (Houseal, 2015). The coherent implementation of all three dimensions emphasizes the idea that science should be a knowledge building endeavor rather than just a memorizing endeavor by leading science teaching towards inquiry-based learning (Duncan and Rivet, 2013). This idea matches the goal of NGSS to not just update the science content being addressed to students, but to shift the way that K-12 science is developed and implemented in order to lead students towards science proficiency (NGSS Lead States, 2013). This hands-on, inquiry-based learning becomes more meaningful to students when they are doing science rather than simply learning science. One way to make the science that students are involved in more meaningful is by applying the idea of PBE into the science classroom. This involves adding a local and community layer to the content and concepts being taught. When local and community topics and problems are incorporated into the science classroom, the themes and topics being discussed have more meaning because they are something that the students can relate to (Sobel, 2004).

**Place-based Education**

**A Definition of PBE**

David Sobel, a leader in place-based education, defines PBE as the following:

> PBE is the process of using the local community and environment as a starting point to teach concepts in language arts, mathematics, social studies, science and other subjects across the curriculum. Emphasizing hands-on, real-world learning experiences, this approach to education increases academic achievement, helps students develop stronger ties to their community, enhances students’ appreciation for the natural world, and creates a heightened commitment to serving as active, contributing citizens. Community vitality and environmental quality are improved.
through the active engagement of local citizens, community organizations, and environmental resources in the life of the school (Sobel, 2004, p. 11).

Hackworth (2015) found that well-designed initiatives could achieve these goals by including PBE principles. The seven principles can be used as a guide in curriculum development in order to adapt and modify any content unit to include the idea, goals, and principles of PBE.

1. Fostering love of one’s place
2. Focusing on local issues and using local experts
3. Learning takes place in the school yard, local community/environment
4. Learning is personally relevant to students
5. Engaging students in investigation, inquiry, and problem solving
6. Engaging students in experiential and project-based learning
7. Learning is interdisciplinary

The definition combined with the PBE principles are referred to as the PBE framework for the purpose of this research study.

**History of PBE**

Although the idea of PBE seems to be a relatively new concept, its basic idea has been around since the 19th century. John Dewey wrote about a disconnect he was noticing among his students. This disconnect was between what was happening in school versus what was happening outside in the real world (Smith, 2002). Dewey noted that the educational system of the 19th century was failing to provide context to what students were learning which resulted in this disconnect between the lived experiences inside and outside the classroom (Smith, 2002). Dewey sought to overcome this at the University of Chicago Lab School at the end of the 19th century. He wrote:
From the standpoint of the child, the great waste in the school comes from his inability to utilize the experiences he gets outside the school in any complete and free-way within the school itself; while, on the other hand, he is unable to apply in daily life what he is learning at school. (Dewey, 1959, p.76-77).

Dewey goes on to suggest that the problem lies in the fact that the children’s minds are inherently drawn to actual phenomena rather than to ideas about phenomena (Dewey, 1959). This is to say that a child will inherently be more curious about watching a tadpole turn into a frog than learning about it in a book. Dewey proposes that learning is not passive and should not be taught that way. Instead, learning should be dynamic and learners should be actively engaged in what they are learning about. Therefore, it needs to be personally relevant and interesting in order to achieve meaningful learning and true understanding (Smith, 2002). Although John Dewey does not directly mention the word “place” his educational philosophy is richly intertwined with the components of place based education (Jayanandhan, 2009).

People often struggle when asked to define “place”. The concept of “place” is made of multidisciplinary components and is complex in nature. Therefore, a definition must reflect its complexity and multidimensional meanings (Jayanandhan, 2009). Lawrence Buell (2005) contends that, “the concept of place…gestures in at least three directions at once: toward environmental materiality, toward social perception or construction, and toward individual affect or bond” (p.63). In other words, place is not only about the physical landscapes and building that surround a person, but is also representative of the feelings that one has towards that place as well as the role that society plays in shaping it (Jayanandhan, 2009). Therefore, one place can hold a variety of meaning depending on the person or people who live there.
The pedagogy of place emphasizes the role of place in education as something to develop and enhance connections between students and their surrounding environment (Jayanandhan, 2009). Examples include the implementation of field trips, interactions with community members and a strong connection between curriculum and the world. This provides learners with a deeper and more meaningful connection to both their community and environment (Jayanandhan, 2009).

“A critical pedagogy of place” takes into consideration two mutually supportive educational traditions, “critical pedagogy” and “PBE”. It argues for a conscious synthesis of these two discourses in order to challenge educators to reflect on the kind of education they pursue in relation to the places they live (Gruenewald, 2003). Gruenewald, presently known as Greenwood, analyzes and synthesizes these two important elements. He also argues that their convergence into a critical pedagogy of place offers a framework for educational theory, research, policy and practice that is much needed for our educational system (Gruenewald, 2003).

The definition of place and PBE must include and provide real world, local experiences in order for students to practice problem solving and critical thinking skills. This can help foster positive attitudes towards the people with whom they share a community and lead them towards a conservation ethic (Theobald and Curtiss, 2000). David Sobel expanded upon the idea of PBE with the notion of using a local community and environment as the starting point to teach other concepts and content (Sobel, 2004).

**The Importance of PBE**

Children are naturally drawn to the actual phenomenon rather than the ideas about these phenomena. It is therefore important to teach students about a place, particularly, their own
place, through hands-on experiences (Smith, 2002). Greenwood states that “classroom-based research is inadequate to the larger tasks of cultural and ecological analysis that is re-inhabitation and decolonization demand” (Gruenewald, 2003). In other words, learning that is only done in the classroom can make it difficult to incorporate the complex dimensions of place. It is when students work with community members and seeking to solve or create solutions to real problems that a critical pedagogy of place be reached (Smith, 2002).

There is also developmental importance in connecting students to their local community. When young students are exposed to large issues that lack context, such as the depletion of the world’s resources or the destruction of the rainforest, they can become disheartened and disengaged to the impact they can have (Sobel, 2007). The goal of PBE is to have students feel empowered to make a difference by addressing local issues first. These developmental claims of Sobel have been paralleled to the writing of Aldo Leopold in his well-known essay “The Land Ethic” (1949), where he writes:

It is inconceivable to me that an ethical relationship to land can exist without love, respect, and admiration for the land, and a high regard to its value…The most serious obstacle impeding the evolution of a land ethic is the fact that our educational and economic system is headed away from, rather than toward an intense consciousness of land (Leopold, 1949, p. 223).

Studies have shown that PBE can help to bridge gaps among generations. PBE encourages the use of community members to share their expertise in schools. This can break down pre-existing barriers and build relationships among students, teachers and community members. In regards to science education, the chance to take field trips, perform research...
projects, and create solutions to real community issues are beneficial in instilling curiosity and engagement in students.

**PBE Principles and Goals**

The seven principles that serve as a foundational base of what PBE is and how it can be used in the classroom should be considered when implementing PBE into curriculum. These principles help to reach the goals of PBE. This is done through facilitating collaborative efforts in research, program design, technical assistance, resource development and dissemination (Marsh-Billings- Rockefeller National Historical Park, NPS & Shelburne Farms, 2015).

Three main goals of PBE include (a) student achievement; (b) community social and economic vitality; (c) and ecological integrity. PBE inherently boosts students’ engagement, which can lead to an increase in academic achievement as well as a sense of personal efficacy as stewards to their local environment and community (Smith, 2002). Lastly, PBE promotes project-based learning where students make tangible contributions to creating solutions to local environmental issues and conserving local environmental quality (Baratt & Baratt-Hacking, 2011).

**Elements of PBE Curriculum Design**

Demarest (2014) presents four elements necessary for designing PBE curriculum. She explains that each element, “can present a palette of colors that teachers can consider as they design curriculum” (Demarest, 2014, p. 41). The four elements include (a) personal connections are the foundation of all learning, (b) local investigations deepen subject understanding, (c) local investigations build holistic understanding of places, and (d) local investigations build opportunity for civic engagement (Demarest, 2014).

**Challenges of PBE**
While the benefits of implementing PBE can outweigh the challenges, it is important to address them. Smith (2007) provides overviews of schools and teachers who have been successful in PBE’s implementation with the conventional constraints that are present in public schools (Smith, 2007). Challenges that arise include aligning the process to standards, wording essential questions to fit the teacher’s purpose, assessing work, and identifying student accomplishments (Demarest, 2014). To combat some of these challenges Demarest (2014) discusses that lessons can be made relevant and personal to students while aligning with standards. For example, if students are learning about maps, a teacher can begin with a special place or their neighborhood. Demarest states that direct experience when grappling with a local or global question, has a better chance of gaining traction in the learner’s mind. It is important to provide assessment check-ins along the way instead of only at the end. This can encourage students to continuously reevaluate and reflect on what it is they are doing and learning (Demarest, 2014).

**English Language Learners**

**Definition of English Language Learner**

The term *English Language Learner* is used to describe students who are from a home where a language other than English is spoken and who are in the process of developing English proficiency for themselves (Robinson-Cimpian, Thompson & Umansky, 2016). The principles of ELL and the strategies and practices that go with them are referred to as the English language learning framework for the purpose of this research study.

**English as a Second Language (ESL) versus English Language Learners (ELLs)**

It is not uncommon to hear both the terms English as a Second Language and ELLs used to describe these students. Hill and Flynn (2013) clearly delineate the two terms as follows: ESL
refers to the specialized traditional programs for students learning English. ESL is a form of instruction that includes teachers who have explicit training to instruct students who are acquiring English as a second language and are often funded by the federal government (Hill & Flynn, 2013). ELL is a term that is used for students who are in general educational classrooms. Since the NCLB act, there has been a great push to keep students learning English in mainstream classrooms (Abedi, 2004).

The term ESL is problematic for some students. First, English may not be a student’s second language. It could be their third, fourth, or even fifth language (Ortmeier-Hooper, 2008). In addition, not all ELLs are from a different country. They can be born and raised in the U.S., but speak a different language at home (Ortmeier-Hooper, 2008). These misinterpretations can lead to emotional and tactical complications because students struggle with what it means to be an “ESL” student (Ortmeier-Hooper, 2008; Robinson et al., 2016). This research project modified curriculum and lesson plans to meet the needs of students learning in the mainstream classroom, therefore, these students will be referred to as English Language Learners (ELLs).

History of ELLs and Where ELLs are today

Forty years ago, in the Lau v. Nichols (1974) case, the Supreme Court ruled that, “There is no equality of treatment merely by providing students with the same facilities, textbooks, teachers, and curriculum; for students who do not understand English are effectively foreclosed from any meaningful education” (Title VI of the Civil Rights Act, 1964). This Act prohibits discrimination on the basis of “race, color, and national origin” in any federally funded program (Robinson-Cimpian et al., 2016). This ruling forced school districts “to take affirmative steps to effectively educate students acquiring English” (Robinson-Cimpian et al., 2016, p. 129).
There is a persistent achievement gap between ELLs and native English speakers. A compilation of reports from 41 state education agencies found that only 18.7% of students who are classified as limited English proficient met state norms for reading in English (Kindler, 2002). The number of ELLs represent the fastest growing segment of the student population (Genesee et al., 2009). From 1991-2002, the number of identified ELLs in K-12 public schools grew 95%, while total enrollment in these schools only increased 12% (Padolsky, 2004).

Robinson et al. (2016) suggested policies helping to ensure the court-mandated equitable education for ELLs can be divided into four crucial topics (a) classifying students as ELLs and then reclassifying them as English proficient as they progress; (b) using students’ primary languages for instruction; (c) accessing grade-appropriate instruction in the content areas, while students are in the process of acquiring English; and (d) designing meaningful assessment and accountability systems for ELLs (Robinson-Cimpian, 2016).

**ELLs and Elementary Science Education**

There is increasing evidence that students will learn English more efficiently when they remain in the classroom rather than being removed to learn English out of context (Coelho, 2003). This is especially true in science-based classes. It is important for teachers to learn and think about how they can integrate both science and language instruction in order to meet the needs of ELLs (Brown & Ryoo, 2008; Lee et al., 2013; Settlage, Madsen & Rustad, 2005). Science teachers often ask, “Can my students learn science before they are proficient in English? And “Do my students need to master basic skills in English before they can participate and engage in scientific inquiry?” (Roseberry & Warren, 2008). As noted above, research shows that students learn language better through context. They do not need to have mastered the language
before they are able to engage in content activities such as scientific inquiry (Roseberry and Warren, 2008).

NGSS and National science education standards provide insight into more effective science learning for language minority students or ELLs (Anstrom, 1997). Anstrom (1997) suggest that the following are used when teaching science with ELLs: (a) involve students in scientific inquiry, (b) advocate for a “less is more” curriculum, (c) teach the language of science, (d) provide comprehensible input in science classrooms, (e) adapt written materials for ELLs, (f) teach problem solving and learning strategies, (g) integrate language and content learning, (h) adapt science instruction, (i) provide teacher demonstration, (j) encourage group investigation, and (k) encourage independent investigation.

Constructivist learning theory posits that learners build new knowledge by integrating new ideas into what has been previously learned. This theory has guided science education for decades (Luria, 1976; Steffe & Gale, 1995; Vygotsky, 1978, 1986). The Framework and NGSS stress that students should participate in inquiry-based science by engaging in the practice of science, which includes an active discourse around a scientific model or phenomenon (NRC, 2012). This ties back to Dewey’s idea that children would rather learn about actual phenomenon rather than ideas about phenomenon.

Science educators often voice the need for a model that helps teachers accomplish both language and the NGSS in order to meet the dual need of learning science and learning English. This can help all students in the classroom use academic science in order to communicate scientific questions, arguments and findings. The intent of structured instruction is to make content comprehensible to ELLs using strategies that are language acquisition driven (Weinburgh et al., 2014). Sheltered instruction emphasizes key vocabulary and provides
scaffolding of activities that help to contextualize science in a way that “lowers the linguistic demand but does not diminish the rigor of the content” (Weinburgh et al., 2014, p. 522).

Weinburgh et al. (2014) attempted to create a model to be a foundation to design for instruction that interrogated the overlap of inquiry-based science and language development. The instructional model emerged from the research they began in 2007. This model, the 5R Instructional Model, aimed to concentrate on the problem of frontloading vocabulary and stating clear, deliberate lesson objectives (Weinburgh, 2009). The 5Rs stand for repeating, revealing, repositioning, replacing and reloading (Weinburgh et al., 2014). It is theoretically grounded on the notion that language constructs and reflects specific sociocultural contexts and builds on the understanding that the language of science is a unique hybrid between natural language and symbols, graphic representations, and specialized action (Gee, 2004; Lemke, 2004; Weinburgh et al., 2014). It is important to note that this model is not a series of steps or linear process, but is a way for teachers to think about lesson/unit planning so that ELLs benefit from effective instruction in both science and language (Weinburgh et al., 2014, p. 535).

**Challenges and Misconceptions**

There are many challenges and misconceptions when working with ELLs in the mainstream classroom such as adapting curriculum, aligning language objectives and content objectives. There are also misconceptions such as children learn second languages quickly. A second misconception is the younger the child the more skilled they are at acquiring a second language. It is important to think about how they acquire a second language the same as they acquired their first language. A third misconception is that if a child can speak the new language that they acquired it. This returns to the differences between BICS and CALP (Cummins, 1999).
BICS standing for Basic Interpersonal Communication Skills and CALP standing for Cognitive Academic Language Proficiency (Cummins, 1999).

Curriculum Design for ELLs

**Sheltered Instruction Observation Protocol (SIOP).** The SIOP model is “an instructional framework that incorporates best practices for teaching academic English and provides teachers with a coherent, usable approach for improving the achievement of their students” (Echevarria, 2000). Its goal is to “provide ELLs with the same high-quality, academically challenging content that native English speakers receive” (Hansen-Thomas, 2008). The SIOP model is comprised of 30 features that are grouped into eight stages. The eight stages are: (a) preparation, (b) building background, (c) comprehensible input, (d) strategies, (e) interaction, (f) practice and application, (g) lesson delivery, and (h) review and assessment (Echevarria, 2000; Nargund-Joshi & Bautista, 2016).

In the **building background** stage the teacher works to explicitly link students’ background, experiences, and prior knowledge to new concepts while introducing key vocabulary. The **comprehensible input** stage emphasizes techniques such as slow and simple speech, body language, gestures, modeling, using visuals and clear and explicit tasks geared toward ELLs language proficiency levels (Krashen, 1985). **Strategies** provide suitable opportunities for ELLs to engage in the lesson through scaffolding and the encouragement of asking questions and promoting higher level thinking skills. **Interaction** is a vital piece of SIOP and language development and content learning because it encourages the interaction of ELLs with peers and teachers that support their learning of both content and language. **Practice and application** involve hands-on and inquiry-based experiences. **Lesson delivery** evaluates how the lesson is being taught and whether or not it is supporting both the content and language
objectives and review and assessment incorporates continuous evaluation of key vocabulary and content concepts by providing feedback and time for students to reflect on what they have learned (Echevarria, 2000; Nargund-Joshi & Bautista, 2016).

Echevarria (2005) discussed two common challenges with SIOP. One issue involves content and language objectives in every lesson. Science teachers, in particular, argue that objectives might get in the way of promoting scientific inquiry. Echevarria (2005) argues that content objectives are based on state standards but do not have to “give-away” the inquiry aspect of the lesson. An example is provided below:

For a second grade lesson, the content objective might be “Students will be able to explore the properties of air.” The language objective might be “Students will be able to describe these properties using words or drawings” (Echevarria, 2005).

A second issue noted with SIOP is that the components are often misinterpreted as a step-by-step process (Echevarria, 2005). Echevarria (2005) discusses the importance that knowledge is reviewed and assessed at the start and throughout the lesson, not only as the last component. Teachers argue that objectives and vocabulary do not need to be presented in the beginning of the lesson but Echevarria (2005) states that some context and vocabulary is needed in order for ELLs to fully grasp what they will be doing in the lesson. However, more content specific terms can be attached to understandings built on personal background information accessed by students initially. This may be after the inquiry or exploratory portion of the lesson (Echevarria, 2005).

**Blending the 5E Learning Cycle and SIOP.** Nargund-Joshi and Bautista (2016) present an approach supporting ELLs language growth in a constructivist-oriented science classroom. They compare and contrast a framework for inquiry-based science instruction call the 5E
Learning Cycle (Bybee, 1997) and a framework for language instruction called the Sheltered Instruction Observation Protocol (SIOP; Echevarria et al., 2002).

Both the 5E learning cycle and SIOP make learning meaningful and relevant to students through hands-on experiential learning, but they each have fundamental differences in their overall goals (Nargund-Joshi & Bautista, 2016). The 5E learning cycle is open-ended. Teachers build on students’ background and prior knowledge and then teach new concepts through exploration and investigation (Nargund-Joshi & Bautista, 2016). In contrast, SIOP urges teachers to first introduce the key content vocabulary and explicitly share the content and language objectives (Echevarria, 2005). Nargund-Joshi and Bautista (2016) believe that the blending of the inquiry-based 5E Learning Cycle with SIOP can create multiple opportunities for students to learn language in the context of science content and develop conceptual understanding of scientific concepts. An example of this can be seen in the Engage stage of the 5E where teachers elicit prior knowledge from students and the building background stage of SIOP where teachers are encouraged to make connections between students’ background knowledge and the scientific concepts they are introducing (Nargund-Joshi & Bautista, 2016). By blending these two instructional models, teachers have the ability to engage all their students, including ELLs (Nargund-Joshi & Bautista, 2016). Other connections can be seen in Figure 4.
Relating the 5E Learning Cycle and SIOP:

<table>
<thead>
<tr>
<th>5 E Learning Cycle</th>
<th>SIOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engage</td>
<td>Preparation</td>
</tr>
<tr>
<td></td>
<td>Building Background</td>
</tr>
<tr>
<td>Explore</td>
<td>Comprehensible Input</td>
</tr>
<tr>
<td></td>
<td>Strategies</td>
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<tr>
<td></td>
<td>Interaction</td>
</tr>
<tr>
<td>Explain</td>
<td>Practice/Application</td>
</tr>
<tr>
<td>Elaborate</td>
<td>Lesson Delivery</td>
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<tr>
<td>Evaluate</td>
<td>Review/Assessment</td>
</tr>
</tbody>
</table>

Figure 4. Relationships between the 5E Learning Cycle and SIOP. Adapted from Nargund-Joshi and Bautista’s Figure 3 (Nargund-Joshi & Bautista, 2016, p.27).

Principles and Strategies for Best Practices for ELLs

Many strategies and best practices ELLs have been developed and modified in the past several decades. Assessment modification strategies, planning, and implementation strategies for science teachers suggested by Bautista and Castaneda (2011) are also included in the following list.

Planning strategies for teaching science to ELLs

1. Know ELLs’ language proficiency levels
2. Align content and language objectives
3. Create a link between background knowledge and science instruction

Science instruction strategies for ELLs
Classroom-based assessment strategies for science teachers

1. Tailor assessment to language proficiency
2. Make the assessment task accessible
3. Diversify content knowledge demonstrations
4. Document student growth

Assessment. Mainstream teachers need practical ways to assess ELL students (Lenski, Ehlers-Zavala, Daniel, & Sun-Irminger, 2006). Lenski et al. (2006) and Bautista and Castaneda (2011) provide the following guiding principles that teachers should consider when assessing ELLs: (a) assessment activities should help teachers make instructional decisions, (b) assessment strategies should help teachers find out what students can do, (c) a holistic context for learning should be considered, (d) assessment activities should be aligned with authentic learning activities, (e) each assessment activity should have a specific objective-linked purpose (p. 25), (f) assessments should be tailored to language proficiency of students, and (g) assessments should document student growth.

Below are detailed descriptions of four main ELL principles. These principles include (a) building background, (b) increasing comprehensibility, (c) increasing interaction, and (d) increasing higher order thinking.

Building Background. Building background includes activating prior experiences, linking new learning from prior learning, and including key vocabulary. Building background is crucial for ELLs because it is how teachers access their prior knowledge and experiences. This
stage helps teachers to explicitly link the new learning to the prior learning as well as introduce key vocabulary necessary to grasp the concept being taught (Nargund-Joshi & Bautista, 2016).

**Scaffolding.** Scaffolding is not only important for ELLs, but it also provides academically challenging instruction for them. The original idea of scaffolding comes from the work of Jerome Bruner. Bruner describes scaffolding as “a process of setting up the situation to make the child’s entry easy and successful and then gradually pulling back and handing the role to the child as he becomes skilled enough to manage it” (Bruner, 1983, p. 60).

Types of scaffolding that should be included when working with ELLs are (a) modeling, (b) bridging prior knowledge with new learning, (c) contextualizing (d) schema building to connect to students’ prior knowledge, (e) re-presenting text so students are seeing information multiple times, and (f) developing metacognition and teaching the process (Walqui, 2006). Modeling encourages teachers to give clear examples of what is requested of them, which helps all students understand what is expected of them. Brainstorms are an example of how modeling can help students understand the expectations teachers have for them. Bridging helps to activate students’ prior knowledge. Contextualizing helps ELLs with the daunting task of reading academic language. By embedding CALP into sensory context by using manipulatives, pictures, film, or other real objects, language can become more accessible. Schema building involves connection to prior learning and connecting them to new knowledge. Re-presenting text creates space for repetition so that ELLs can practice with the new language they have learned in relationship to what they are learning. Lastly, developing metacognition refers to the teaching process. It refers to the ways in which ELLs manage their thinking, being able to apply what they are learning, understanding strategic options available to them, monitoring, evaluating, and adjusting performance, and planning for the future.
Increase Comprehensibility. In order for teachers to increase comprehensibility they must incorporate specific strategies into their lessons to help students’ link vocabulary (Kaufman, 2007). Lesson delivery techniques, such as using slow and simple speech, body language and gestures, modeling, visuals and clear explanation of tasks specifically targeted for ELLs are other examples (Nargund-Joshi & Bautista, 2016). In 2002 the organization WIDS (World-Class Instructional Design and Assessment) was formed. Three states were involved in its initial development. These states were Wisconsin, Delaware, and Arkansas. The mission of WIDA to advance academic language development and academic achievement for linguistically diverse students through high quality standards, assessments, research, and professional development for educators. It strives to be one of the best resources in pre-K-12 education for language learners. (University of Wisconsin, 2014).

Increase Student Interaction. Increasing interaction can be done through learning with a partner, cooperative learning and collaboration, and setting up the classroom where teacher is not at the center (Kaufman, 2007). This key element in second language acquisition encourages both language development and content learning (Nargund-Joshi & Bautista, 2016). It can occur between teacher and student or student and student. Scaffolding can be used to help increase interaction. One framework suggests scaffolding that emphasizes the interactive social nature of learning and the contingent, collaborative nature of support and development (Walqui, 2006).

The figure below represents a scaffolding model put out by the international journal of bilingual education and bilingualism. It demonstrates scaffolding in regards to the interaction happening among students and teachers.
**Figure 5.** Scaffolding Model for ELLs interacting with peers and teachers. Adapted from van Lier, 2004; Walqui, 2006.

**Increase Higher Order Thinking.** Teachers should support ELLs’ learning through the consistent use of scaffolding and questioning techniques within the lesson. (Kaufman, 2007; Nargund-Joshi & Bautista, 2016). Figure 6 is a model showing the progression of how students can reach higher order thinking. This can be useful with ELLs by working with them to evaluate, synthesize, and analyze.
Figure 6. Bloom’s taxonomy: the steps needed to help students reach higher-order thinking through the use of foundational knowledge and comprehension in order for students to analyze, synthesize, and evaluate what they have learned. Adapted from Benjamin Bloom’s framework (Bloom, 1956, http://www.bu.edu/ctl/teaching-resources/course-design/).

The literature on curriculum development, assessment techniques, inclusion and alignment of NGSS in a unit and lessons, principles of PBE, and principles and best practices for ELLs helped to inform the development of this 5th grade curricular science unit. The literature points to how NGSS, PBE, strategies for ELLs can be used to teach science. However, there is gap in the literature, which incorporates the development of a science unit that not only aligns to the NGSS, but also is locally oriented and adapted to meet the needs of ELLs. This research project was intended to accomplish this goal.
Chapter 3

Methodology

Introduction

This research project aimed to develop a 5th grade ecology unit based on the Wyoming sagebrush ecosystem. The unit sought to incorporate the three dimensions of NGSS, the principles of Place Based Education (PBE), current research being conducted by UW scientists on the sagebrush ecosystem, and strategies and best practices for English language learners (ELLs). The goal was to create a science unit that is both meaningful and accessible to all students within a 5th grade classroom and (a) increase understanding of scientific concepts related to the sagebrush ecosystem; (b) incorporate diverse instructional strategies, intended to enhance the student’s connection to place and (c) include strategies and best practices for ELLs in order to meet these students’ language needs without sacrificing content. Nine, 75-90 minute lessons were developed to be piloted in spring 2016 in a 5th grade classroom in Baggs, Wyoming and ultimately be made available for all Wyoming teachers by the Biodiversity Institute, at the University of Wyoming.

This research was guided by the following questions:

How can the research literatures on the three dimensions of NGSS, PBE principles, and ELL strategies and best practices, guide the development of a 5th grade unit about the sagebrush ecosystem?

Further, how can this unit:
• Guide the connection of students to a local ecosystem through local scientists?
• Align with appropriate 5th grade Next Generation Science Standards focused on ecology and ecosystems?
• Include appropriate ELL strategies and best practices in order to make this science unit available for all students in a given classroom?

This study involved a literature review of curriculum development, NGSS, PBE, and ELLs. This data and information gathered from the literature review addressed the practices and processes used to develop the 5th grade science unit, *A Sagebrush Expedition*.

**Curriculum Development**

A framework for the unit was created according to the three stages of backwards design presented by Wiggins and McTighe (2005). The first stage of backwards design consists of an overview and purpose statement. This stage is also comprised of the desired results of the unit, which includes transfer goals, enduring understandings, essential questions, knowledge and skills. The reasons for the ordering of these tasks in curriculum development are they are the components that students will walk away with after they have completed the unit and they are not intended to be answered after one or two lessons. Instead each lesson should give students another piece of the puzzle to guide students towards these goals, understandings and essential questions (Wiggins & McTighe, 2005).

Three transfer goals, three enduring understandings, two essential questions, four knowledge acquisitions, and three skill acquisitions were developed for this stage. These were based on scientific understandings and skills, human impacts on the natural world, and connection to place. Stage one was developed in alignment with the overall goals for the unit, as well as the chosen NGSS.
The second stage of backwards design looks at the assessment evidence within the unit. Students’ conceptions and skill levels will be uncovered by a variety of assessments in order for both teacher and students to understand what they know and what they can do. There are different types of assessments that are encouraged in backwards design. These include prior knowledge and skill assessments, performance tasks and other evidence that allows students to demonstrate what they have achieved and how they have achieved Stage one (Wiggins & McTighe, 2005). For “A Sagebrush Expedition”, three types of assessments were used throughout the unit. These were diagnostic, formative and summative assessments. Diagnostic assessments were used to identify preconceptions, lines of reasoning, and learning difficulties among students. Formative assessments implicated into curriculum were used to inform instruction and provide feedback to students on their learning. Finally, summative assessments were used to measure and document the extent to which students achieved the goals and enduring understandings of the unit, as well as their ability to answer the essential questions (Keeley, 2008).

Stage three of backwards design focuses on the development of learning plans. This stage of backwards design involves the development of activities and experiences that will make the desired results happen. When developing stage three, it is important to think about what knowledge and skills students will need in order to achieve the desired results. It is also important to consider the teaching methods, sequence of lessons, and resource materials needed for the curriculum to be successful.

The 5E learning cycle was incorporated into the suggested procedure section of each lesson plan. I used this instructional model, which is based on the constructivist view of learning in which teachers identify students’ misconceptions and prior knowledge and then provide time
for students to explore and investigate. It is followed by students reconstructing their knowledge and understanding (Bybee, 1997). This model is referred to as a learning cycle because it encourages that assessment and evaluations is done throughout the entire lesson plan, instead of only at the end.

**Next Generation Science Standards (NGSS)**

One goal of the unit was to align it with the NGSS. In order to do this a bundle of standards was chosen based on NGSS Lead States (2013) recommendations for 5th grade learners. Working with the Biodiversity Unit at the University of Wyoming, it was determined that the science unit would be about ecology, specifically about ecosystems. This narrowed down which standards would be appropriate to use. Four standards were chosen based on the above criteria. Three standards were in the life sciences with core ideas that include interdependent relationships, the movement of matter and energy in an ecosystem, and the idea that plants chiefly get what they need to grow from air and water. The fourth standard was from the earth system sciences and involves the core idea of how humans impact the land. This standard helps students make connections among the abiotic and biotic components of a landscape, and understand the impacts and interactions that humans have with that landscape.

Another goal was to include all three dimensions of NGSS because the Framework and NGSS specify that the three dimensions should not be taught in isolation. The disciplinary core ideas (DCI) should be constantly connected to cross cutting concepts (CCC) and consistently explore through science and engineering practices (SEP) (Houseal, 2015).

This led to the inclusion of two CCC: (a) systems and system models and (b) energy and matter (NGSS Lead States, 2013). This also led to the inclusion of three SEP: (a) engaging in argument from evidence; (b) developing and using models; and (c) obtaining, evaluation, and
communicating information (NGSS Lead States, 2013). The NGSS also include the nature of science (NOS). These NOS concepts were included in the unit based on the grade level: (a) scientific investigations use a variety of methods; (b) science knowledge is based on empirical evidence; (c) scientific knowledge assumes an order and consistency in natural systems; and (d) science is a human endeavor (NGSS Lead States, 2013). Table 1 below visually represents the DCIs, CCCs, and SEPs, and Table 2 represents the NOS concepts that were included to inform the development of the nine lesson plans.

Table 1

<table>
<thead>
<tr>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
<th>Science and Engineering Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS1.C: Organization for matter and energy flow in organisms (Plants acquire their material for growth chiefly from air and water.)</td>
<td>Energy and Matter: matter is transported into, out of, and within systems</td>
<td>Engaging in argument from evidence</td>
</tr>
<tr>
<td>LS2.A: Interdependent relationships in ecosystems</td>
<td>Systems and System Models: a system can be described in terms of its components and their interactions.</td>
<td>Developing and using models</td>
</tr>
<tr>
<td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems</td>
<td>Systems and System Models: a system can be described in terms of its components and their interactions.</td>
<td>Developing and using models</td>
</tr>
<tr>
<td>ESS3.C: Human Impacts on Earth Systems</td>
<td>Systems and System Models: a system can be described in terms of its components and their interactions.</td>
<td>Obtaining, evaluating, and communicating information</td>
</tr>
</tbody>
</table>
Table 2

*NOS concepts used in the unit “A Sagebrush Expedition”*

<table>
<thead>
<tr>
<th>Nature of Science Concepts</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific investigations use a variety of methods</td>
<td>Scientific methods are determined by questions</td>
</tr>
<tr>
<td></td>
<td>Scientific investigations use a variety of methods, tools, and techniques</td>
</tr>
<tr>
<td>Scientific knowledge is based on empirical evidence</td>
<td>Scientific findings are based on recognizing patterns</td>
</tr>
<tr>
<td></td>
<td>Scientists use tools and technologies to make accurate measurements and observations</td>
</tr>
<tr>
<td>Scientific knowledge assumes an order and consistency in natural systems</td>
<td>Science assumes consistent patterns in natural systems.</td>
</tr>
<tr>
<td></td>
<td>Basic laws of nature are the same everywhere in the universe</td>
</tr>
<tr>
<td>Science is a human endeavor</td>
<td>Men and women from all cultures and backgrounds choose careers as scientists and engineers.</td>
</tr>
<tr>
<td></td>
<td>Most scientists and engineers work in teams.</td>
</tr>
<tr>
<td></td>
<td>Science affects everyday life.</td>
</tr>
<tr>
<td></td>
<td>Creativity and imagination are important to science</td>
</tr>
</tbody>
</table>

Note: DCIs, CCCs, SEPs, and NOS concepts used in the unit “A Sagebrush Expedition”. These were chosen using the NGSS Lead States (2013) specifically looking at standards addressed in 5th grade.

**Place-Based Education (PBE)**

I wanted the unit to be place-based due to the literature informing that this approach to education increases academic achievement, helps students develop stronger ties to their community, and enhances students’ appreciation for the natural world. PBE also creates a heightened commitment to serving as active, contributing citizens through emphasizing hands-on, real world learning experiences (Sobel, 2004). According to NGSS, 5th grade students are working on interdependent relationships, movement of matter and energy within an ecosystem, how plants use air and water to grow, and the impacts that humans have on the environment. These standards discuss “what” to teach, not “how” to teach. This provides a perfect opportunity
to incorporate PBE in order to reach these standards in a way that is local and meaningful to the students.

The Biodiversity Institute at the University of Wyoming wanted to create a science unit that would engage students in learning about the biodiversity and ecosystems of Wyoming. By incorporating PBE principles into the unit, I was not only reaching NGSS goals, but the goals of the Biodiversity Institute.

Table 3, below, diagrams how each PBE principle was incorporated into the unit.

Table 3

<table>
<thead>
<tr>
<th>Place-Based Education Principles and how they were used</th>
<th>How explicitly used in the “Sagebrush Expedition” Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fostering love of one’s place</td>
<td>Two field trips to the sagebrush ecosystem.</td>
</tr>
<tr>
<td>2. Focusing on local issues and using local experts</td>
<td>Focus on local examples for each lesson plan.</td>
</tr>
<tr>
<td></td>
<td>Incorporation of UW research scientists.</td>
</tr>
<tr>
<td>3. Learning takes place in the school yard, local</td>
<td>Lessons took place outside and addressed local</td>
</tr>
<tr>
<td>community, and local environment</td>
<td>community and environmental issues.</td>
</tr>
<tr>
<td>4. Learning is personally relevant to students</td>
<td>Unit topics were related to students’ lives and</td>
</tr>
<tr>
<td></td>
<td>experiences.</td>
</tr>
<tr>
<td>5. Engaging students in investigation, inquiry, and</td>
<td>Engagement in mini scientific investigations,</td>
</tr>
<tr>
<td>problem solving</td>
<td>inquiry-based activities such as final research</td>
</tr>
<tr>
<td></td>
<td>project.</td>
</tr>
<tr>
<td>6. Engaging students in experiential and project-based</td>
<td>Inclusion of experiential and hands-on components in</td>
</tr>
<tr>
<td>learning</td>
<td>lesson plans. Project-based</td>
</tr>
<tr>
<td></td>
<td>learning through Each 1 Teach 1 and final research</td>
</tr>
<tr>
<td></td>
<td>assignment.</td>
</tr>
<tr>
<td>7. Learning is interdisciplinary</td>
<td>Not explicitly defined by potential for incorporating</td>
</tr>
<tr>
<td></td>
<td>common core standards.</td>
</tr>
</tbody>
</table>

Note: Place-based Education principles and how they were explicitly used in the unit A Sagebrush Expedition.
One PBE principle focuses on the importance of incorporating local issues and using local experts to make learning more meaningful and relevant to students (Smith & Sobel, 2010). This principle was accomplished through the use and inclusion of local research being conducted by graduate students and faculty at the University of Wyoming. The research was about the sagebrush ecosystem and its various components. I chose five scientists to work with, based on the alignment of their research to the NGSS and overall goals of the unit. The researchers and their research included: (1) Dr. Kyle Palmquist, researches water retention in sagebrush soils in order to determine the future of this ecosystem in regards to climate change; (2) Courtney Duchardt, who studies the interdependent relationships between species who live in short grass, tall grass, sagebrush and their ecotones; (3) Jason Carlisle, who’s focus is umbrella species concept and how sage grouse acts as an umbrella species for the sagebrush ecosystem; (4) Megan Wilson, studies insects that return to sites that have been disturbed and reclaimed - such as the areas around oil well pads; and (4) Caitlin Rottler, focuses her research on carbon and nitrogen in the soil and vegetation around oil well pads that have been reclaimed.

These scientists’ research was incorporated into the lessons of this unit in order to focus on (a) local issues using local experts, (b) meaningful examples of the topics and concepts being taught, (c) real research taking place in the local and the sagebrush communities of Wyoming, and (d) a partnership between the Biodiversity Institute of the University of Wyoming and the Little Snake River Elementary School of Baggs, Wyoming.

**English Language Learners (ELL)**

Based on the literature four ELL principles were incorporated into the unit. These included (a) building background, (b) increasing comprehensibility, (c) increasing interaction, and (d) increasing higher order thinking. These principles were chosen in order to meet the
language needs of ELL students without sacrificing content. I chose to include a variety of research-based strategies and best practices used to adequately integrate these four principles through additions and modifications to the unit. Although the entirety of the SIOP model is not explicitly included within the lesson plans, many of its components fall within the four principles chosen for this research project.

**Building background.** Building background has three parts: (a) activating prior-experiences; (b) activating past learning to a new concept; and (c) key vocabulary. These three background building components included in each lesson in order to adapt the lesson for ELL students. I used a variety of strategies for each component, which can be seen in Table 3. A language objective linked to concept objectives was included in each of the nine lessons in order to link past learning to new concepts while meeting the language needs of ELL students.
Table 4

*Strategies used for building background for ELL students*

<table>
<thead>
<tr>
<th>Building Background</th>
<th>Activating prior experiences</th>
<th>Linking past learning to new concepts</th>
<th>Key vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategies Used</td>
<td>Turn and talk</td>
<td>Share objectives</td>
<td>Word walls</td>
</tr>
<tr>
<td></td>
<td>Concept Maps</td>
<td>Lesson connections</td>
<td>Word “draw”</td>
</tr>
<tr>
<td></td>
<td>Realia (pictures and objects)</td>
<td>Popcorn review</td>
<td>Fly swatter game</td>
</tr>
<tr>
<td></td>
<td>Brainstorming</td>
<td>Visuals</td>
<td>Acting out vocab</td>
</tr>
<tr>
<td></td>
<td>Sharing stories</td>
<td>Kinesthetic link</td>
<td>Word review games</td>
</tr>
<tr>
<td></td>
<td>Creating a common experience</td>
<td>Interactive review</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peer questioning</td>
<td>Student journals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Connections to past experiences</td>
<td>Hands-on experiences and field trips</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Role-playing</td>
<td>Think- pair- share</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Field Trips</td>
<td>Inquiry</td>
<td></td>
</tr>
</tbody>
</table>

Note: Strategies used for building background for ELL Students. Strategies used for building background were chosen using literature from Echevarria, Vogt, and Short (1994).

**Increasing Comprehensibility.** Increasing comprehensibility was also incorporated into the unit through intentional additions to suggested procedures and modifications. These strategies and best practices were incorporated in order to meet the language needs of ELL students while not sacrificing the content that was being taught. These strategies can be seen in Table 5.

Including language objectives that are linked to the content objectives of a lesson plan is another way to increase comprehensibility. A language objectives was therefore developed and incorporated into each of the nine lesson plans. Each language objective was based on the content objective using the “can do descriptors for the levels of English language proficiency” by WIDA (World-Class Instructional Design and Assessment). The lesson plans were modified based on a level 2, level 3, and level 4 English language proficiency. These levels were chosen
based on being at the middle levels. They were also chosen to provide modifications that were geared towards the average ELLs. However, these can be adjusted based on the ELLs that are in a given 5th grade classroom. The WIDA table used to create the language objectives can be seen in Figure 7.
For the given level of English language proficiency, with support, ELLs can:

<table>
<thead>
<tr>
<th></th>
<th><strong>Level 1</strong> Enterprising</th>
<th><strong>Level 2</strong> Beginning</th>
<th><strong>Level 3</strong> Developing</th>
<th><strong>Level 4</strong> Expanding</th>
<th><strong>Level 5</strong> Bridging</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Listening</strong></td>
<td>• Point and state words, phrases</td>
<td>• Sort pictures, objects according to oral instructions</td>
<td>• Locate, select, order information from oral descriptions</td>
<td>• Compare/contrast functions, relationships from oral information</td>
<td>• Draw conclusions from oral information</td>
</tr>
<tr>
<td></td>
<td>• Follow one-step oral directions</td>
<td>• Follow two-step oral directions</td>
<td>• Follow multi-step oral directions</td>
<td>• Analyze and apply oral information</td>
<td>• Construct models based on oral discourse</td>
</tr>
<tr>
<td></td>
<td>• Match oral statements to objects, figures, or illustrations</td>
<td>• Match information from oral descriptors to objects, illustrations</td>
<td>• Categorize or sequence oral information using pictures, objects</td>
<td>• Identify cause and effect from oral discourse</td>
<td>• Make connections from oral discourse</td>
</tr>
<tr>
<td><strong>Speaking</strong></td>
<td>• Name objects, people, pictures</td>
<td>• Ask WH-questions</td>
<td>• Formulate hypotheses, make predictions</td>
<td>• Discuss stories, issues, concepts</td>
<td>• Engage in debates</td>
</tr>
<tr>
<td></td>
<td>• Answer WH (who, what, when, where, which) questions</td>
<td>• Describe pictures, events, objects, people</td>
<td>• Give speeches, oral reports</td>
<td>• Explain phenomena, give examples, and justify responses</td>
<td>• Express and defend points of view</td>
</tr>
<tr>
<td></td>
<td>• Restate facts</td>
<td>• Describe processes, procedures</td>
<td>• Offer creative solutions to issues, problems</td>
<td>• Retell stories or events</td>
<td></td>
</tr>
<tr>
<td><strong>Reading</strong></td>
<td>• Match icons and symbols to words, phrases, or environmental print</td>
<td>• Locate and classify information</td>
<td>• Sequence pictures, events processes</td>
<td>• Interpret information or data</td>
<td>• Conduct research to glean information from multiple sources</td>
</tr>
<tr>
<td></td>
<td>• Identify concepts about print and text features</td>
<td>• Identify facts and explicit messages</td>
<td>• Identify main ideas</td>
<td>• Find details that support main ideas</td>
<td>• Draw conclusions from explicit and implicit text</td>
</tr>
<tr>
<td></td>
<td>• Select language patterns associated with facts</td>
<td>• Select language patterns associated with facts</td>
<td>• Use context clues to determine meaning of words</td>
<td>• Identify word families, figures of speech</td>
<td></td>
</tr>
<tr>
<td><strong>Writing</strong></td>
<td>• Label objects, pictures, diagrams</td>
<td>• Makes lists</td>
<td>• Produce bare bones expository or narrative texts</td>
<td>• Summarize information from graphics or notes</td>
<td>• Apply information to new contexts</td>
</tr>
<tr>
<td></td>
<td>• Draw in response to a prompt</td>
<td>• Produce drawings, phrases, short sentences, notes</td>
<td>• Compare/contrast information</td>
<td>• Edit and revise writing</td>
<td>• React to multiple genres and discourses</td>
</tr>
<tr>
<td></td>
<td>• Produce icons, symbols, words, phrases to convey messages</td>
<td>• Give information requested from oral or written directions</td>
<td>• Describe events, people, processes, procedures</td>
<td>• Create original ideas or detailed responses</td>
<td>• Author multiple forms/genres of writing</td>
</tr>
</tbody>
</table>

*Figure 7. CAN DO Descriptors for the Levels of English Language Proficiency, Pre-K-12. Developed from WIDA (World-Class Instructional Design and Assessment. [https://www.wida.us/standards/CAN_DOs/](https://www.wida.us/standards/CAN_DOs/).*
**Increasing Interaction.** Increasing interaction can be seen throughout the lesson plans. I chose the following strategies to increase the interaction among students and between students and teacher in order to encourage both language development and content learning (Nargund-Joshi & Bautista, 2016). These strategies can be seen in Table 5.

**Increasing higher order thinking.** Increasing higher order thinking is an important principle to use when working with ELL students. The research states that teachers should support ELL students’ learning through the consistent use of scaffolding and questions techniques within the lessons. The questions asked should promote higher order thinking instead of only trying to grasp whether an ELL student understands the literal meaning of vocabulary (Kaufman, 2007; Nargund-Joshi & Bautista, 2016). These can also be seen in Table 5.
Table 5

Strategies and practices used to increase comprehensibility, interaction, and higher order thinking.

<table>
<thead>
<tr>
<th>Increase comprehensibility strategies and practices</th>
<th>Increase interaction strategies and practices</th>
<th>Increase higher order thinking strategies and practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands-on manipulatives and explorations</td>
<td>Jigsaw activities</td>
<td>Use of Bloom’s taxonomy</td>
</tr>
<tr>
<td>Real pictures and objects</td>
<td>Think-pair-share</td>
<td>Encourage students to explain</td>
</tr>
<tr>
<td>Video clips and visuals</td>
<td>Elbow partners</td>
<td>Engagement in argument from evidence</td>
</tr>
<tr>
<td>Peer-peer conversations including peers asking peers questions</td>
<td>Partner reading</td>
<td>Generalize understanding and apply what has been learned</td>
</tr>
<tr>
<td>Small group or pair work to lower affective filter</td>
<td>Having students be the teachers</td>
<td>Classify and categorize</td>
</tr>
<tr>
<td>Connection to prior knowledge</td>
<td>Hands-on explorations and experiences</td>
<td>Think-out-loud and brainstorm sessions</td>
</tr>
<tr>
<td>Repetition</td>
<td>Acting and role play</td>
<td>Compare and contrast</td>
</tr>
<tr>
<td>Summarization</td>
<td>Small group work and projects</td>
<td>Synthesize information learned</td>
</tr>
<tr>
<td>Review</td>
<td>Inquiry and exploration</td>
<td>Develop models to explain concepts</td>
</tr>
<tr>
<td>Acting out and role play</td>
<td>Reflection time</td>
<td>Interpret data observed and collected</td>
</tr>
<tr>
<td>Step-by-step instructions</td>
<td></td>
<td>Communicate knowledge and understandings</td>
</tr>
<tr>
<td>Modeling</td>
<td></td>
<td>Expanding on learning through making connections</td>
</tr>
<tr>
<td>Scaffolding</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Strategies and practices used to increase comprehensibility, interaction, and higher order thinking. These strategies and practices were suggested by Kaufman (2007) and Nargund-Joshi & Bautista (2016).

The unit was piloted over four weeks in spring 2016 with Jamie Litvinoff’s 5th grade class at Little Snake River Elementary School in Baggs, Wyoming. Many revisions were made to the unit and each lesson plan as they were being piloted. ELL modifications were made more explicit by adding a rationale column within the lesson plans that explains how particular
strategies or practices were being used to meet the four ELL principles. Diagnostic, formative and summative assessments were used in the development of this science unit and adjusted based on the literature in regards to NGSS, PBE, and ELLs.

**Challenges**

There were several challenges that presented themselves throughout the development of the unit. These challenges included: how the unit should look and what should be included, what NGSS would be most appropriate for teaching about the sagebrush ecosystem, coordinating with the research scientists from UW, which ELL strategies and practices should be included, lesson plan development, and time.

Figuring out what the unit should look like and what needed to be included was an evolving process throughout this study. The three stages of backwards design helped to guide the overall goals of the unit, but making sure each lesson plan reached these goals could be difficult. There were certain activities or experiences that seemed appropriate, but a lack of connection to the overall goals and essential questions of the unit required they be removed. When implementing the 5E learning cycle, the *Evaluation* phase was placed at the end. Thus implying a *linear progression* rather than a *learning cycle*. Suggested procedures needed to be adjusted to include evaluations and assessment check-ins throughout the procedures within each lesson plan.

The NGSS helped guide which DCIs, CCCs, and SEPs, should be included in the unit. Since the unit was focused on learning about a local ecosystem it made sense to create either a 3rd or 5th grade unit. The number of lesson plans needed to adequately represent the goals of the unit was a challenging process. In the beginning, lesson plan topics were chosen based on what *could* be taught in regards to the sagebrush ecosystem, rather than what *should* be taught. Another challenge emerged from working with the UW research scientists. Several scientists
were contacted and five were chosen to be involved in the unit based on their interest and research. Although there was room for flexibility within the unit and the lesson plans, their research needed to match the overall goals of the unit in order to be included. In the end, nine lesson plans were developed to reach these goals and certain lesson plans incorporated the research being done by the UW research scientists.

Another challenge in partnering with the UW research scientists was finding time to collaborate. Coordinating times to meet with them to discuss their research proved to be difficult due to busy schedules. When creating the short videos about their research collaboration was needed among the scientists, IT staff member who helped with filming and editing, and goals of the unit and Biodiversity Institute. The videos, unfortunately, took longer to produce than expected. Therefore, only a few were included when the unit was piloted. Links to videos did not always function properly, which also led to the videos not being included in the pilot.

The research indicated many strategies and best practices that can be used when working with ELL students. Often these strategies and best practices are chosen based on the proficiency level of the ELL students present in a given classroom. A teacher’s preference and teaching style also can determine which strategies and practices are used. This created difficulty in knowing which ones would be the most useful to include. A variety of strategies and practices were included throughout the unit with rationales for why they were chosen in hopes to help instructors understand the basis of their use. Many strategies and practices were included in order to give teachers a variety to choose from.

The development of the lesson plans was a dynamic process that continuously evolved. Originally the lesson plans included the NGSS but PBE and ELL principles were not explicitly indicated. Further revisions included which PBE principles were present in each lesson plan as
well as which ELL strategies and best practices were incorporated. A rationale behind each ELL strategy or practice was included to justify how the lesson plans were being modified. The assessment check-ins and evaluations were also revised and changed several times as the unit evolved.

Time was a huge factor in the development of this unit. Developing curriculum can be a huge undertaking and the addition of the NGSS, PBE, and ELL frameworks added to this. I found it to be difficult to develop lesson plans that I would not be teaching myself. I learned that when developing curriculum for others; explicit goals, instructions and progressions must be present. I also realized that including background information for teachers is crucial because some teachers may be new to what will be taught in a given lesson plan. Making sure to give adequate time for each lesson plan was also a difficult task. After piloting the unit, I discovered through feedback that most lessons were too long and included too many parts for the time allotted. In order to accommodate for this, some lessons have been recommended to be taught over several days. This will increase the overall time of the unit. However, some components were removed to create more succinct procedures, while others were highlighted as extra.

The many challenges that arose throughout the development of this science unit led to many revisions and modifications. These revisions are intended to make the unit more accessible to teachers who choose to use it in the future, or who choose to use this unit as a framework for future development.

Results of the methods described in this chapter can be seen in Chapter 4, which is the science unit, *A Sagebrush Expedition*, developed for this research project.
Chapter 4

Sagebrush Unit

Overview

The Science Unit, *A Sagebrush Expedition* is an educational resource developed for the Biodiversity Institute and Wyoming 5th grade teachers. The curricular unit was created to be used inside the classroom, outside in the schoolyard, and in the local sagebrush ecosystem. These lessons and activities are supported by research that combines educational literature and experts in the field of science education, the sagebrush ecosystem, and the instruction of English language learners. This chapter provides the basis of each area of the 5th grade science unit. These areas include: (a) bodies of knowledge (b) overview and purpose statement (c) desired results (d) assessment evidence (e) learning plan overviews (f) weekly themes and daily progression, (h) lesson plan format and (g) the nine 75-90-minute lesson plans.

Bodies of Knowledge

There are three bodies of knowledge addressed throughout the unit. These bodies are (a) connections to science, ecology, and scientific practices and skills, (b) human impacts on the natural world, and (c) connection to place. Each body of knowledge includes themes related to the sagebrush ecosystem.

Unit Details

Presented below are the overview and purpose statement of the unit. The desired results, assessment evidence, learning plan overviews and the suggested weekly themes and daily progression are also included.
Overview and Purpose Statement of Unit

Key for Bodies of Knowledge

Connections to science, ecology, and scientific practices and skills
Human Impacts on the Natural World
Connection to Place

<table>
<thead>
<tr>
<th>Overview and Purpose Statement</th>
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</thead>
<tbody>
<tr>
<td>Building science literacy through inquiry-based exploration and hands-on experiences empowers students to problem solve and think critically about current issues facing the scientific community. It gives them tools to successfully navigate and interact positively with their local ecosystem and community. Further, it allows them to observe the natural and social world, draw conclusions based on evidence, and make informed and productive decisions.</td>
</tr>
</tbody>
</table>

This unit will give students the opportunity to explore the diversity of life found within the sagebrush ecosystem. They will explore this landscape through scientific and historical land use lenses. Students will build capacity in scientific inquiry skills through observations and conducting field investigations of the multiple patterns and processes that make up this unique ecosystem by using the landscape equation as a model. They will be encouraged and challenged to participate and influence their peers as they practice analytical reasoning skills and make deep connections to the sagebrush ecosystem in which they live.

During this unit, students will have the opportunity to build individual scientific literacy skills as they make observations, conduct small investigations that introduce the landscape and its parts, establish a connection to place, and practice the skills of a naturalist and scientist. They will become more familiar with the special qualities of the sagebrush ecosystem, while learning principles of ecosystem science. They will be challenged to make meaning of their observations, compare patterns in the landscape, synthesize their learning, and demonstrate understanding.

The purpose of this unit is not only to teach students about the intricacy and complexity of the sagebrush ecosystem, but also to have it meet the Next Generation Science Standards (NGSS), incorporate Place-Based Education (PBE) principles, and include strategies and best practices for English language learners (ELLs). To this end there are four main goals for this unit in an effort for students to better understand the Nature of Science this unit will focus on:

1. Understanding that scientific investigations use a variety of methods, scientific knowledge is based on empirical evidence, scientific knowledge assumes an order and consistency in natural systems, and science is a human endeavor.
2. Incorporate the seven principles of place-based education.
3. Establish a relationship between the Biodiversity Institute at the University of Wyoming and the Little Snake River Valley School that can be continued into the future.
4. Meet the learning levels of all students in diverse classrooms with a distinct focus on English language learners without sacrificing content.
**NGSS incorporated:**

<table>
<thead>
<tr>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
<th>Science and Engineering Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS1.C: Organization for matter and energy flow in organisms (Plants acquire their material for growth chiefly from air and water.)</td>
<td>Energy and Matter: matter is transported into, out of, and within systems</td>
<td>Engaging in argument from evidence</td>
</tr>
<tr>
<td>LS2.A: Interdependent relationships in ecosystems</td>
<td>Systems and System Models: a system can be described in terms of its components and their interactions.</td>
<td>Developing and using models</td>
</tr>
<tr>
<td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems</td>
<td>Systems and System Models: a system can be described in terms of its components and their interactions.</td>
<td>Developing and using models</td>
</tr>
<tr>
<td>ESS3.C: Human Impacts on Earth Systems</td>
<td>Systems and System Models: a system can be described in terms of its components and their interactions.</td>
<td>Obtaining, evaluating, and communicating information</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nature of Science Concepts</th>
<th>Description</th>
</tr>
</thead>
</table>
| Scientific investigations use a variety of methods | • Scientific methods are determined by questions  
• Scientific investigations use a variety of methods, tools, and techniques |
| Scientific knowledge is based on empirical evidence | • Scientific findings are based on recognizing patterns  
• Scientists use tools and technologies to make accurate measurements and observations |
| Scientific knowledge assumes an order and consistency in natural systems | • Science assumes consistent patterns in natural systems.  
• Basic laws of nature are the same everywhere in the universe |
| Science is a human endeavor | • Men and women from all cultures and backgrounds choose careers as scientists and engineers.  
• Most scientists and engineers work in teams.  
• Science affects everyday life.  
• Creativity and imagination are important to science |

**Place-Based Education Principles Incorporated:**
1. Fostering love of one’s place  
2. Focusing on local issues and using local experts  
3. Learning takes place in the school yard, community, and local environment  
4. Learning is personally relevant to students  
5. Engaging students in investigation, inquiry, and problem solving  
6. Engaging students in experiential and project-based learning  
7. Learning is interdisciplinary

**English Language Learner Principles Incorporated:**
1. Building Background: Activating prior knowledge, linking prior experiences to new learning experiences, introducing new and key vocabulary  
2. Increase Comprehensibility  
3. Increase Interaction
### Stage One: Desired Results

#### Transfer

**Transfer Goals:** *Students will be able to independently use their learning to understand that...*
- **TG1** - Science is a process that helps us gain a collective understanding of how the world works, it is a lifelong process, it is applicable every day, and accessible to everyone.
- **TG2** - Humans are an interconnected part of the natural world and can have both positive and negative impacts.
- **TG3** - Cultivating a sense of place, through intentional interactions, inspires curiosity about one’s community and helps to develop a conservation ethic.

#### Meaning

**Enduring Understandings:** *Students will understand that...*
- **U1** - The sagebrush ecosystem is made up of many moving parts that are all interconnected to one another.
- **U2** - Human actions can have both positive and negative impacts on the sagebrush ecosystem.
- **U3** - The use of naturalist and scientific practices and skills can lead to a deeper understanding of their local community.

**Essential Questions:** *Students will keep considering...*
- **Q1** - What is special about my community and what can I learn from it?
- **Q2** - How can my actions, as an informed citizen, impact my community?

#### Acquisition

**Knowledge:** *Students will...*
- **K1** – Be able to identify and explain various reasons of what makes their community special.
- **K2** - Know ways that humans can positively and negatively impact the sagebrush ecosystem.
- **K3** – Know how to use scientific investigation to explore the interdependent relationships and interactions in the sagebrush ecosystem.
- **K4** - Be able to explain how matter cycles and energy flows through the sagebrush ecosystem.

**Skills:** *Students will be skilled at...*
- **S1** – Identifying and recognizing the three components of the landscape equation and giving examples of each component.
- **S2** - Various scientific processes in order to explore, design, and implement scientific investigations, including engaging in argument from evidence, developing and using models to address systems and interdependent relationships, and obtaining, evaluating, and communicating information.
- **S3** – Using naturalist’s tools, such as field guides, dichotomous keys, binoculars, magnifying glasses, transect lines, soil cores, ribbon tests, and observation to identify notable flora and fauna in the sagebrush ecosystem.
Stage Two: Assessment Evidence

### Prior Knowledge and Skill Assessment:
*Students conceptions and skill levels will be uncovered by...*

- **Pre and Post Surveys:** Students will be given a pre-survey to assess their prior knowledge and attitudes towards the sagebrush ecosystem and science practices. They will be given a post-survey at the end of the unit to re-assess their knowledge and attitudes towards the sagebrush ecosystem and science practices.

- **Concept Map:** Students will create a large classroom concept map to assess their prior knowledge about the sagebrush ecosystem. This will be re-visited at the end of the unit to assess what students learned through adding a second layer of knowledge to their original concept map.

- **Assessment Probes:** Students will be given various assessment probes in order to elicit their ideas about various topics such as living and nonliving things, what they already know about the sagebrush ecosystem. These assessment probes will be designed to discover students’ prior knowledge in order to guide learning and discovering more about each topic.

- **Informal Assessments:** For individual lessons, instructors will use a variety of informal methods to assess knowledge. These will include diagnostic assessments to reach students’ prior knowledge and misconceptions. These formative assessments are intended to help the teacher and students evaluate what they have learned and what they are able to do with this knowledge.

### Performance Tasks:
*Students will demonstrate that they really understand through...*

**PT1/1 – Naturalist/Reflection Journal:** Students will create a naturalist journal which will exhibit student engagement, exploration and learning, with emphases on the naturalist and scientific knowledge and skills practiced throughout the unit. It will be constructed from experiences both inside and outside of formal classes. This will be the place for students to record naturalist skills, such as species accounts, field and course notes. Finally, students will record their reflections on leadership, place, and cultural aspects of the sagebrush ecosystem.

**PT2 – “Each 1 Teach 1” on local flora & fauna:** Students will be asked to prepare an ‘Each-One-Teach-One’ lesson on a local flora, fauna or abiotic topics in regards to the sagebrush ecosystem. An “Each 1 Teach 1” lesson involves students working in pairs or small groups to investigate further into a topic of their choice. They will then present their findings to the entire class. Each pair of group of students will present their lesson during an allotted amount of time and will be given feedback from their peers. Students will take notes during each other’s lessons to hone in on a more in-depth understanding of their local ecosystem.

### Other Evidence:
*Students will demonstrate that they achieved Stage 1 through...*

**OE1/1 – Mini SCI (Scientific Investigation):** Students will explore a question through science investigation using the science circle and reflect whether this process provides deeper understanding of the topic.

**OE2/2/2/2 – Unit Participation, Understanding and Reflection:** Students will end the unit by reflecting on their overall participation during lessons and projects, their understanding of what they learned throughout the unit, and reflect on the overall experience of learning about place through a scientific lens. This will be demonstrated by adding a second layer to the sagebrush concept map with different color post-it notes. They will write about and illustrate their experiences with sagebrush, science, and place through a reflection piece in their naturalist journals.
<table>
<thead>
<tr>
<th>PT3/3/3 – Culminating Synthesis Research Project:</th>
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<tbody>
<tr>
<td>Students will participate in a culminating final research project where they will be able to express what they have learned throughout the unit about content and processes. Students will work in small groups and have the opportunity to research a topic they are curious to explore further. These topics will be based on lessons that were covered throughout the unit. Students will participate in the scientific process using the science circle as a model. In doing so they will continue to think about what is special about their community and what they can learn from it. Students will have time to think of their question, make a hypothesis, decide how they will gather data, gather the data and creatively prepare how they will share this information with others. During their presentation they will share what they have learned as well as make connections to the three components of the landscape equation, including the impacts that humans have on the topic they choose to research.</td>
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</table>
Stage Three: Learning Plan Overviews

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<tr>
<th>Focus Learning Events: Student success at transfer, meaning and acquisition depends upon…</th>
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</thead>
</table>

**NGSS Goals:**

1. Support an argument that plants get the materials they need for growth chiefly from air and water.
2. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.
3. Obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment.

**Nature of Science Goals:**

1. Through mini scientific investigations a variety of scientific methods, tools and skills can be learned.
2. Observations and data collection lead to scientific knowledge that is based on empirical evidence.
3. Scientific knowledge assumes an order and consistency in natural systems that can be demonstrated through exploration of the movement of matter in an ecosystem.
4. Science is a human endeavor.
5. Science addresses questions about the natural world and material world.

**Lesson Plan Overviews:**

**LE1: Introduction to Place Through Maps and Sagebrush:**
Lesson 1 aims to get students to start thinking about place, community, and science. Creating maps of their own community and exploring maps in WyoBio will introduce students introduced to the scientific process or “Science Circle”. Students will be given the opportunity to (a) use their observation skills to create their own map as well as explore other maps (b) learn how information from observations can help in creating maps and (c) how maps can help them have a better understanding of their community.

**LE2: Landscape Equation (Landscape = Abiotic + Biotic + Culture):**
Lesson 2 focuses on breaking down the components of a landscape through the lens of an equation. Students will gain knowledge about the interdependent relationships between the abiotic, biotic and cultural components of a landscape in order to lead them to a deeper understanding of an ecosystem as a whole. Students will use observation skills to group and categorize objects in order to lead them to deciphering the landscape equation. Through hands-on activities and group work students will have the opportunity to understand the components of a landscape, learn new scientific vocabulary, create a model that demonstrates the interconnected relationships and describes the movement between these components, and begin to think about how humans play a role. These skills and hands on learning activities are significant in leading students to a deeper understanding of their local landscape; the sagebrush ecosystem.

**LE3: The Importance of Air and Water in the Sagebrush Landscape:**
Lesson 3 explores some of the abiotic factors that influence the sagebrush landscape. Students will review what they learned from the landscape equation through a fun game of Simon Says. They will then think about why plants rely chiefly on air and water to create their own food in order to grow. The emphasis here will be on the idea that plant matter comes mostly from air and water not from soil. Through inquiry, students will design a mini research investigation that explores deeper into the relationship between these abiotic factors and plants, allowing students the opportunity to witness how matter can be transported into, out of and within a system.

**LE4: The Dirt on Soil in the Sagebrush:**
Lesson 4 aims to have students dig deeper into soil. Although plants rely chiefly on air and water to grow, which they learned about last lesson, soil is extremely important for plants as it provides stability, nutrients, and holds water. Students will be given the opportunity to learn about how a local research scientist uses soil to predict the future of the sagebrush ecosystem as they learn how to test and take samples of the soil. They will learn about the different particle sizes in the soil and how this affects water retention, different layers that can be found in soil, and test the pH. They will then be asked to apply this knowledge to continue the story of their local sagebrush landscape as they work to gain a better understanding of this ecosystem.

**LE5: The Cycle of Matter within the Trophic Levels:**
Lesson 5 facilitates that students understand the meaning of matter and how it moves into, out of and within the sagebrush ecosystem among plants, animals, insects, decomposers and the environment. They will be given the opportunity to create a model demonstrating understanding of the different trophic levels and how matter moves between these layers through exploration, acting, application, and synthesis work. They will investigate how all species are connected, as well as, explore the idea that the removal of one species can affect the whole system. Students will develop a deeper understanding of the interconnected relationships that exist within the sagebrush landscape.

**LE6: Plant Identification and Dichotomous Keys:**
Lesson 6 begins the comparison and contrast of different plant species that are present in the sagebrush ecosystem. Students will focus on shrubs found in this landscape. Students will understand how dichotomous keys work by an activity where they will sort and categorize plant samples based on their unique characteristics. Students will understand the importance of using specific adjectives when describing and sorting plants in order to identify them by species. They will learn more about shrub species that exist in the sagebrush ecosystem through the practice of identifying samples using a simple dichotomous key. Students will continually make connections between how plants fit into the landscape equation throughout the lesson.

**LE7: Exploring Insects in the Sagebrush Landscape:**
Lesson 7 explores insects and other arthropods that exist within the sagebrush ecosystem. Students will investigate what kinds of insects they can find around their schoolyard and identify them to order. They will learn how to make bug traps in order to catch a variety of insects. They will be able to compare the insects found in their schoolyard to insects they find on a field trip to the sagebrush. Students will learn more about a particular order of insects by creating a species account of an insect they found. This account will include the insects’ importance to the sagebrush ecosystem, what parts of the sagebrush ecosystem does it rely on, and what connections do they have with humans.

**LE8: Sage Grouse: An Umbrella Species:**
Lesson 8 integrates role-playing as conservation biologists. Students will discover the meaning of an umbrella species and how the protection of an umbrella species can indirectly protect many other species that also rely and use the same habitat. Students will work in small groups to make a decision on which species to protect using evidence to justify their choice. Students will then have the opportunity to learn more about how the Greater Sage Grouse is considered an umbrella species in the sagebrush ecosystem through the research of UW student Jason Carlisle.

**LE9: Humans in the Sagebrush Landscape:**
Lesson 9 examines the various impacts that humans have on the sagebrush ecosystem. Through observations and explorations student will gain a better understanding of both the positive and negative impacts that humans can have on a landscape and how humans are an interconnected part of the natural world. Students will explore the idea of stewardship and how this effects the awareness of local issues.
Field Trip to the Sagebrush Ecosystem:
The goal of taking a field trip into the sagebrush ecosystem is to observe and apply the scientific concepts and skills that have been learned throughout the unit. Students will be given the opportunity to practice steps of the science circle through making observations as they explore the landscape, asking questions about their observations, and practice making hypotheses using evidence to justify their statements. Students will have the opportunity to demonstrate the learned scientific skills. Students will apply concepts such as the landscape equation through the creation of a landscape quilt. In addition, the field trip offers students the opportunity to learn new skills such as plant and bird identification as they travel in the land of the sagebrush.
### Unit Progression

**Unit Progression:** For deeper understanding, students will experience the following sequence

<table>
<thead>
<tr>
<th>Lesson Plans 1-2</th>
<th>Themes of Each Week</th>
<th>Daytime Learning Events</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction to Place, the Scientific Process, Ecology, and the Sagebrush Ecosystem</strong></td>
<td></td>
<td>Day 1: Introduction to Place through Maps and Sagebrush (Pre Survey)</td>
</tr>
<tr>
<td><strong>Landscape Equation (L = Abiotic + Biotic + Culture)</strong></td>
<td></td>
<td>Day 2: The Landscape Equation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lesson Plans 3-5</th>
<th>Themes of Each Week</th>
<th>Daytime Learning Events</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abiotic: Plants rely on Air and Water for nutrients</strong></td>
<td></td>
<td>Day 3: The Importance of Air and Water in the Sage (Abiotic)</td>
</tr>
<tr>
<td><strong>Abiotic: Soil composition and importance for plants in the sagebrush</strong></td>
<td></td>
<td>Day 4: The Dirt on Soil in the Sagebrush (Abiotic)</td>
</tr>
<tr>
<td><strong>Abiotic and Biotic: Trophic Levels: Movement of matter and energy among flora and fauna in the sagebrush ecosystem</strong></td>
<td></td>
<td>Day 5: Trophic Levels (Abiotic and Biotic)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field Trip #1</th>
<th>Themes of Each Week</th>
<th>Daytime Learning Events</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mini SCI</strong></td>
<td></td>
<td>Day 6: Field Trip #1 to Sagebrush Ecosystem</td>
</tr>
<tr>
<td><strong>Reflective Practice: Naturalist Journal</strong></td>
<td></td>
<td><em>(Include at least 1 Mini SCI in lessons above and at least 1 reflection in Naturalist Journal)</em></td>
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</table>

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<thead>
<tr>
<th>Lesson Plans 6-7</th>
<th>Themes of Each Week</th>
<th>Daytime Learning Events</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Expert Groups: Each 1 Teach 1 Activity: Students having the opportunity to become the educators</strong></td>
<td></td>
<td>Day 7: Introduction to Each 1 Teach 1 Activity and work time</td>
</tr>
<tr>
<td><strong>Biotic: Plant Identification</strong></td>
<td></td>
<td>Day 8: Plant Identification</td>
</tr>
<tr>
<td><strong>Biotic: Exploring Insects in the Sagebrush</strong></td>
<td></td>
<td>Day 9: Exploring Insects of the Sagebrush Landscape</td>
</tr>
<tr>
<td><strong>Mini SCI</strong></td>
<td></td>
<td>Day 10: Each 1 Teach 1 Presentations</td>
</tr>
<tr>
<td><strong>Reflective Practice: Naturalist Journal</strong></td>
<td></td>
<td><em>(Include at least 1 Mini SCI in lessons above and at least 1 reflection in Naturalist Journal)</em></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Each 1 Teach 1</th>
<th>Themes of Each Week</th>
<th>Daytime Learning Events</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biotic and Culture: Sage grouse acting as an Umbrella Species</strong></td>
<td></td>
<td>Day 11: Sage Grouse: An Umbrella Species (Introduce Final Synthesis Project)</td>
</tr>
<tr>
<td><strong>Culture: Human Impacts on the Sagebrush Landscape</strong></td>
<td></td>
<td>Day 12: Humans in the Sagebrush Landscape</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Lesson Plans 8-9</th>
<th>Themes of Each Week</th>
<th>Daytime Learning Events</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Synthesis: Human Culture and the Sagebrush Ecosystem Project</strong> Introduce and give time to work on final synthesis project incorporating all parts of the landscape equation</td>
<td></td>
<td>Day 13: Work day for final project</td>
</tr>
<tr>
<td><strong>Field Trip #2</strong> Students will collect data and observations for group research projects</td>
<td></td>
<td>Day 14: Field trip #2 to Sagebrush Ecosystem</td>
</tr>
<tr>
<td><strong>Mini SCI</strong></td>
<td></td>
<td><em>(Include at least 1 Mini SCI in lessons above and at least 1 reflection in Naturalist Journal)</em></td>
</tr>
<tr>
<td><strong>Reflective Practice: Naturalist Journal</strong></td>
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<tr>
<th>Final Project</th>
<th>Themes of Each Week</th>
<th>Daytime Learning Events</th>
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</thead>
<tbody>
<tr>
<td><strong>Synthesis: Human Culture and the Sagebrush Ecosystem Project</strong></td>
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<td>Day 15: Continue to work on final Project</td>
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<td></td>
<td></td>
<td>Day 16: Continue to work on final Project and presentations</td>
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<tr>
<td></td>
<td></td>
<td>Day 17: Continue to work on final Project and presentations</td>
</tr>
</tbody>
</table>
Lesson Plan Format

Each lesson plan in the *A Sagebrush Expedition* unit follows a carefully prepared format. The purpose of this format is to provide consistency throughout the unit that can be easily understood for instruction. Each lesson plan includes the following: (a) title, (b) overview of the lesson and the main takeaway, (c) learner outcomes, (d) getting ready; which includes materials, preparation, and location of lesson, (e) NGSS standards addressed, (f) how many lessons and length of time suggested, (g) unit connections, (h) specific lesson language objective, (i) building background section which includes how to activate students’ prior experiences, how to link new learning from prior learning, and vocabulary, (j) key vocabulary words, (k) background information for the teacher, (l) common student misconceptions and student challenges, (m) suggested procedures, (n) assessment check ins, recognized by a symbol similar to this (D1), and (o) references. Each lesson plan includes NGSS connections, PBE principles that are highlighted in purple, and highlighted ELL modifications. The first four lesson plans highlight the ELL modifications as well as rationale for how each strategy or practice meet one of the four ELL principles: building background, increase comprehensibility, increase interaction, or increase higher order thinking. The remaining five lesson plans include a colored highlighting system of the ELL strategies and practices in relationship to which principle they are targeting. Figure 6 below represents the key used for the highlighting incorporated into the lesson plans.
Table 6

*Essential Questions within each lesson plan.*

<table>
<thead>
<tr>
<th>Lesson Plans (LP)</th>
<th>LP 1</th>
<th>LP 2</th>
<th>LP 3</th>
<th>LP 4</th>
<th>LP 5</th>
<th>LP 6</th>
<th>LP 7</th>
<th>LP 8</th>
<th>LP 9</th>
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<tbody>
<tr>
<td>Essential Questions</td>
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<tr>
<td>What is special about my community and what can I learn from it?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>How can my actions, as an informed citizen, impact my community?</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>X</td>
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Note: Essential questions within each lesson plan. Table shows which essential questions each lesson plan aims to address.
Table 7

*Three Dimensions of NGSS within each lesson plan*

<table>
<thead>
<tr>
<th>Lesson Plans (LP)</th>
<th>LP 1</th>
<th>LP 2</th>
<th>LP 3</th>
<th>LP 4</th>
<th>LP 5</th>
<th>LP 6</th>
<th>LP 7</th>
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<th>LP 9</th>
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<tbody>
<tr>
<td>Disciplinary Core Ideas</td>
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<td>LS1.C: Organization for matter and energy flow in organisms (Plants acquire their material for growth chiefly from air and water)</td>
<td>X</td>
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<td>LS2.A: Interdependent relationships in ecosystems</td>
<td>X</td>
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<td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems</td>
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<td>ESS3.C: Human Impacts on Earth Systems</td>
<td>X</td>
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<td>Crosscutting Concepts</td>
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<td>Energy and Matter: matter is transported into, out of, and within systems</td>
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<td>Systems and System Models: a system can be described in terms of its components and their interactions</td>
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<td>Scientific and Engineering Practices</td>
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<td>Engaging in argument from evidence</td>
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<tr>
<td>Developing and using models</td>
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<td>Obtaining, evaluating, and communicating information</td>
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Note: Where the three dimensions of NGSS are incorporated within the lesson plans. Chosen using NGSS Lead States (2013). Visual representation of where these dimensions are present within the unit.
Lesson 1: Introduction to Place through Maps and Sagebrush

Unit: 5th Grade Ecology Unit: A Sagebrush Expedition

Lesson: Introduction to Place through Maps and Sagebrush

Overview: This lesson aims to initiate students’ thinking about place, community, and science. Creating maps of their own community and exploring maps in WyoBio will introduce students to the scientific process or “Science Circle”. Students will be given the opportunity to (a) use their observation skills to create their own map as well as explore other maps (b) learn how observations can help inform our maps and (c) how maps can help us have a better understanding of our own community or place.

Main Take Away: Students will be introduced to the unit and the essential questions they will be working on answering over the next several weeks. Students will begin thinking about their local community and environment and how they impact it as humans as well as how it impacts them. They will further explore their community through the exploration of a variety of maps.

Learner Outcomes

Students will be able to...

- Understand the importance of place through mapping out their homes and community.
- Understand that the Sagebrush Ecosystem is a part of their local community and comprised of many interdependent relationships.
- Use the WyoBio website to look at local plant and animal distribution maps to better understand their local landscape and to gain a deeper understanding of what exists there.

Getting Ready

Materials: Pre-surveys, Computers to access WyoBio, large paper for map activity, pencils and colored pencils.

Preparation: Print out pre-surveys for each student, arrange for student access to WyoBio (classroom or computer lab), and familiarize them with WyoBio.

Location: In a classroom and a computer lab where students have internet access.

Length of Time: 2 Lessons

Approximately 60-75 minutes each

NGSS Standard(s) Addressed:

- **Disciplinary Core Idea:** ESS3.C: Human impacts on earth systems
- **Science and Engineering Practices:** Developing and using models

Place-Based Principle(s) Addressed:

- Fostering love of one’s place
- Learning is personally relevant to students

Unit Connections

(How specific lesson connects to overall goals and objectives of the unit)

Transfer Goals: Students will be able to independently use their learning to understand that...

- TG1- Science is a process that helps us gain a collective understanding of how the world works, it is a process, it is applicable every day, and accessible to everyone.
- TG2- Humans are an interconnected part of the natural world and can have both positive and negative impact on it. Learning how to positively impact the world helps to develop a conservation ethic.

Unit Essential Question: Students will keep considering...

- What is special about my community and what can I learn from it?
- How can my actions, as a human, impact my community?
### Specific Lesson Content Objectives: *Students will be able to…*
- Understand the importance of place through mapping out their homes and community.
- Understand that the Sagebrush Ecosystem is a part of their local community and comprised of many interdependent relationships.
- Use the WyBio website to look at local plant and animal distribution maps to better understand their local landscape and to gain a deeper understanding of what exists there.

### Specific Lesson Language Objectives: *Students will be able to…*
- Understand the meanings of map, local, and distribution in order to work with the WyBio website.
- Point to specific parts of a map (compass rose, keys, distance measurement, etc.) when asked by instructor.

### Key Vocabulary Words:
- **Place and Community**
- Maps (Key, Compass rose, layers)
- WyBio
- Sagebrush Ecosystem

### Background Information for the teacher:

**WyBio:** The following is an excerpt from the “introduction and about sections” of the WyBio website:

**Wyoming Biodiversity Citizen Science Initiative - or WyBio is a website created by the Biodiversity Institute at the University of Wyoming.** It is a project intended to connect all people, especially Wyoming citizens, with information about Wyoming’s biodiversity – plants, animals and fungi. We seek to bring together many or all of the different citizen science datasets collected and maintained by a variety of groups across the state, making all biodiversity data available to all interested persons. It is a place where one can research any information about a plant or animal in Wyoming. One can virtually work with scientists, input data that will be used in research projects, help survey the land for all the organisms found, and test hypotheses about why organisms exist in a certain place, change their locations or population sizes over time, and more. Additionally, we aim to create educational experiences connected with Wyoming biodiversity data so that students and citizens become more knowledgeable about and connected with organisms and ecosystems in their own state.

WyBio can a wonderful tool to use in the classroom too. It can give students the opportunity to connect more deeply to their place by looking at and manipulating various maps. For example, students can learn how to map vegetation in their specific community as well as look at how the vegetation differs across the entire state of Wyoming. They can then use this information to think about what animals may live in certain areas depending on the vegetation that grow there. They can also begin to look at species range maps to see the distribution of animals across the state. The website also gives students the opportunity to replace background maps with satellite images and layer different maps to get an overall picture of a particular area.

The project was initiated in February 2012, with the first version of the website launched in summer 2014. We will continue to roll out enhanced versions of WyBio (including more functionality and improved graphics) through summer 2015.

**Sagebrush Ecosystem:**

The vast sagebrush ecosystem of the western United States is a thriving landscape that sustains virtually all western wildlife for at least part of each year. This ecosystem is often referred to as the sagebrush sea because it covers approximately 166 million acres (67 hectares), an expansive landmass of semi-arid lands divided in half by the north-south-running Rocky Mountains. There are eleven western states that compose the ecosystem; Colorado, Wyoming, South Dakota, North Dakota, Montana, Idaho, Washington, Oregon, California, Nevada, and Utah.

The term, “sagebrush sea” well describes the rolling gray-green landscape, but suggests a featureless monoculture, which is an incorrect perception of the sagebrush ecosystem.

The great migrations of pronghorn, mule deer, and elk flow through valleys covered with sagebrush east of the Rockies.
Greater Yellowstone’s grizzly bears, the highest concentration in the Lower 48 states, rely on the sagebrush ecosystem while roaming a large territory. In spring and fall, hundreds of bird species, a number of them biologically bound to sagebrush, migrate the Pacific Flyways and Central Flyway on the eastern flank of the Rocky Mountains. Additionally, the sagebrush ecosystem encompasses riparian areas and woodlands. In these habitats, the sagebrush ecosystem is dominated by nearly thirty species, subspecies and hybrid of sagebrush shrub (Showalter, 2015).

**Building Background for Students: (ELL principle)**

**Activate Prior Experiences:**
Students will:
1. Brainstorm the meaning of science and how it can be considered an expedition.
2. Engage in a pre-survey to access their prior knowledge about science and the sagebrush ecosystem.
3. Brainstorm the meaning of community.
4. Brainstorm what is common in maps.
5. Share stories about experiences in the sagebrush ecosystem.

**Link to New Learning from Prior Learning:**
1. Explore different types of maps to figure out what is common throughout and how they differ.
2. Engage in the WyoBio website to explore different types of maps about Wyoming.
3. Create their own map connecting what they learned about maps and what they know about their own community.

**Vocabulary:**
A word wall will be created in the classroom where all new and key vocabulary can be visually displayed. Words can be written, drawn or a combination of both.

**Common Student Misconceptions/Student Challenges:**
- All maps are the same
- The natural world is not a part of our local community and our local community is not part of the natural world.

**Materials:**
- Pre-surveys
- Computers to access WyoBio
- Maps of Wyoming
- Large paper for map activity and pencil
- Colored pencils

<table>
<thead>
<tr>
<th>Set-up:</th>
<th>Have pre-surveys printed and ready</th>
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<tbody>
<tr>
<td></td>
<td>Familiarize yourself with WyoBio</td>
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<td></td>
<td>Access to enough computers for students to work in pairs</td>
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<table>
<thead>
<tr>
<th><strong>Lesson Agenda</strong></th>
<th><strong>Suggested Procedure</strong></th>
<th><strong>ELL Rationale</strong></th>
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<tbody>
<tr>
<td><strong>Engage:</strong></td>
<td><strong>Introduction:</strong></td>
<td>• Building background activities</td>
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<tr>
<td>Approximately 30-</td>
<td>• Introduce the unit by forecasting to students: “Over the next several weeks we are going to have the opportunity to delve into the science of ecology through a sagebrush expedition. We will learn how we, as humans, can impact this ecosystem and how this ecosystem can impact us. We will also be working with several research scientists from the University of Wyoming on this expedition. First we are going to think about and discuss what science, ecology, and expedition mean.”</td>
<td>• Brainstorm in small groups allows students to activate prior knowledge and increase interaction.</td>
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<td>45min</td>
<td>• Pose the following questions to students:</td>
<td>• Pre-surveys</td>
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<td><strong>Introduction of</strong></td>
<td>o What is science? Why might we think of science as a journey or expedition?</td>
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<td>unit and build</td>
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<td>background</td>
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<td>knowledge</td>
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</table>
If ecology, the study of the relationships that exist between organisms and their physical surrounding, is a part of science, how can it be a journey or expedition?

- Have students discuss potential answers to these questions within a small group. Have groups share out to the class. (D1)
- Emphasize that each lesson is a process and a journey and that we will be a part of this journey throughout the next several weeks.
- Introduce the two essential questions that students will work on answering over the next several weeks.

**Pre-Survey:**
- Give out pre-surveys for students to fill out. (D2)
- When students are finished with the surveys, hand out naturalist journals. Explain these will be where they record all their observations, questions, data, notes, and drawings for this unit. It will be a graded piece of the unit. *(See attached Rubric)*

**Introduction to Place:**
- Explain to students that we are going to start this journey with the observation of our place and local community.
- Write the word “community” on a large piece of paper. Then turn to an elbow buddy (pair students) to talk about what this word means.
- While students are discussing, hand out 2-3 post-it notes to each student.

**Community Concept Map:**
- Give the following directions, “Write or draw one thing that you think is related to the word community on each post-it note. Then silently, stick this idea on the poster, branching out from the word, “community”. (D3)
- Potential student responses: (people, family, buildings, home, school, trees, river, robin, sagebrush, bees, vegetables, friends, mushrooms, cats, dogs, horses, clouds, sun, etc.)
- Discuss a few post-it notes that were added. Inform students that they will be adding to this throughout the unit. Students should be encouraged to add ideas as they think of them.

**Explore:**
- Approximately 30-45min

**Exploration of different types of Maps to help students learn more about their local community and environment.**

**Maps:**
- Pose the following question:
  - “What do you know about maps? What can we find on a map?”
- Give students a moment to think about this question and write down 1-2 ideas in their naturalist journals. Then have students turn to an elbow buddy and discuss what they know about maps.
- Ask each pair to write 1-2 of their ideas on the board to create an overall list.

- Students will help students activate prior knowledge about science and the sagebrush ecosystem.
- Community concept map will increase comprehensibility because it will connect prior knowledge and link to new knowledge.
- Post-it notes can be written or drawn which will increase comprehensibility by lowering affective filter.

- Students will activate prior knowledge in pairs about maps. This will increase interaction and comprehensibility.
<table>
<thead>
<tr>
<th>Potential student responses: (roads, rivers, mountains, houses, directions, towns, hiking trails, etc.)</th>
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<tbody>
<tr>
<td>• Hand out various Wyoming maps to small groups of students. Inform them that we are trying to add to our list by studying what we find on these maps.</td>
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<tr>
<td>• Discuss what has been added with the class and have students point out a few similarities between the maps and a few differences. Ask them, “What things appear on all the maps? Why do you think these are important?” (F1)</td>
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### Following class:

#### Explore:
Approximately 30 min

Continuation of exploration of maps and community.

- Explain to students, “Now that we have explored maps and some of the things that we can find on a map let’s explore a website created by the Biodiversity Institute at the University of Wyoming. This website allows us to explore and learn about other types of maps such as species range maps, vegetation maps, and human use maps across the state of Wyoming. Let’s learn more about our local community by exploring different maps of the area to find out what species of plants and animals live in our local landscape.”

#### WyoBio Activity:
(Each student or pair of students should have access to a computer in a computer lab setting)

- Explain to students that, “citizens, just like you, can help to make these observations to influence maps. This is called citizen science.” This is how many of these maps were created.

- Introduce students to the University of Wyoming website, WyoBio.
  - o Explain how to navigate to the map portion of WyoBio. Explain that maps can have different layers depending on a specific area of research. For example, someone might want to only look at water sources (lakes, rivers, steams) in Wyoming and can select that layer.

- **Guiding activities to be done with instructor. Have students:**
  - o Find their school’s location on the map.
  - o Turn on the sage grouse layer so they can see how much land is being conserved as core areas for the sage grouse.
  - o Turn on the vegetation layer and figure out what vegetation is most abundant in or around their local community.
  - o Turn on the critical habitat layers for big game and sage grouse to what parts of Wyoming are critical for these animal species.

- Give students time to explore the different map layers individually or with hands-on exploration of WyoBio will help increase interaction as students get to manipulate the different maps. Working in pairs will also increase interaction.

- Connecting new vocabulary to what students already know
Elaborate: Approximately 30min

Application: Students will create their own maps.

Map Activity:
- Announce that students will have the opportunity to map out and draw their own community in small groups.
- Each group will be given a large piece of paper and pencil and asked to draw a map of where they live.
  - Encourage them to put in as much detail as possible, including what they found to be important in the previous activities:
  - Have students think about:
    - Things they found that are always included in maps
    - What pieces can be included to help someone else understand your community better by looking at this map.
- This project will be graded based on group participation, inclusion of key parts of a map (compass rose, distance measurements, key), and inclusion of at least 2 things students learned from WyoBio. (S1)

Reflection Prompts: Approximately 15min
- Pose the following questions:
  - “What does a map explain to us about our community and our place?”
  - “Why are maps important and why do you think that humans use them?”
- Have students think about these questions and write 2-3 bulleted answers for each question in their naturalist journal.

Evaluations and Assessment Check ins:
- Questions and discussion will help access student’s prior knowledge about science, ecology, expedition, place and community. (D1)
- Pre-Surveys will access students’ prior knowledge about science, scientific research, and the sagebrush ecosystem. (D2)
- “Community” concept map will help discover what students’ conception of community is. (D3)
- Provides insight on (a) what students are learning from making observations about maps and (b) gives them the opportunity to point out similarities and differences among the various maps. (F1)
- Assesses what students have learned about maps and how they can connect us better to our local community. (S1)

- ELLs will work in pairs or small groups. (D1)
- Assessments will activate prior knowledge, increase interaction, and increase comprehensibility. (S1)

References:
Wyoming Biodiversity Citizen Science Initiative (WyoBio), Biodiversity Institute, University of Wyoming.
Lesson 2: The Landscape Equation

Overview: This lesson is an inquiry of breaking down the components of a landscape through the lens of an equation. Students will gain knowledge about the interdependent relationships between the abiotic, biotic and cultural components of a landscape in order to lead them to a deeper understanding of an ecosystem as a whole. Students will use observation skills to group and categorize objects in order to lead them to deciphering the landscape equation. Through hands-on activities and group work students will have the opportunity to understand the components of a landscape, learn new scientific vocabulary, create a model that demonstrates the interconnected relationships and describes the movement between these components, and begin to think about how humans play a role. These skills and hands on learning activities are significant in leading students to a deeper understanding of their local landscape; the sagebrush ecosystem.

Main Take Away: Students will be able to grasp the different components present in an ecosystem, specifically the sagebrush ecosystem, through using the landscape equation as a model.

<table>
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<tr>
<th>Learner Outcomes</th>
<th>Getting Ready</th>
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<tr>
<td><strong>Students will be able to...</strong></td>
<td><strong>Materials:</strong> Abiotic objects or pictures, Biotic objects or pictures, Cultural objects or pictures, L = A + B + C sign, large piece of paper, “The Sagebrush Sea” documentary, naturalist journals and pencil.</td>
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<tr>
<td>• Make connections using the interdependent relationships between the three parts of the landscape equation help us understand the sagebrush ecosystem as a whole.</td>
<td><strong>Preparation:</strong> Gather pictures and objects of abiotic, biotic, and cultural components. These should include objects that are found in the sagebrush ecosystem and objects that are not. Review the lesson to make sure activities are understood. Make sure to have access to “The Sagebrush Sea” documentary and means to play it.</td>
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<tr>
<td>• Understand how humans are a part of the sagebrush ecosystem and can have both positive and negative effects on its landscape.</td>
<td><strong>Location:</strong> In the classroom or some activities can be done outside in an open space.</td>
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<tr>
<td>• Give examples of the components of the landscape equation (Landscape = Abiotic components + Biotic components + Cultural components), specifically for the sagebrush landscape.</td>
<td><strong>Length of Time:</strong> 1-2 Lessons Approximately 60-75 minutes each</td>
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NGSS Standard(s) Addressed:
- **Disciplinary Core Ideas:**
  - LS2. A: Interdependent Relationships in Ecosystems
  - ESS3.C: Human impacts on Earth systems
- **Cross Cutting Concepts:**
  - Systems and System Models: A system can be described in terms of its components and their interactions.
- **Science and Engineering Practices:**
  - Developing and Using Models to describe

Place-Based Principle(s) Addressed:
- Engaging students in investigation, inquiry, and problem solving.
**Connections to Nature of Science: 5-LS2-1:**
- Science, Models, Laws, Mechanisms, and Theories explain Natural Phenomena. Science explanations describe the mechanisms for natural events.

**Unit Connections**
(How specific lesson connects to overall goals and objectives of the unit)

**Transfer Goals:** *Students will be able to independently use their learning to understand that…*
- TG1- Science is a process that helps us gain a collective understanding of how the world works, it is a lifelong process, it is applicable every day, and accessible to everyone.
- TG2- Humans are an interconnected part of the natural world and can have both positive and negative impacts.
- TG3- Cultivating a sense of place, through intentional interactions, inspires curiosity about one’s community and helps to develop a conservation ethic.

**Unit Essential Question:** *Students will keep considering…*
- What is special about my community and what can I learn from it?
- How can my actions, as a human, impact my community?

**Specific Lesson Content Objectives:** *Students will be able to…*
- Make connections using the interdependent relationships between the three parts of the landscape equation help us understand the sagebrush ecosystem as a whole.
- Understand how humans are a part of the sagebrush ecosystem and we can have both positive and negative effects on its landscape.
- Give examples of the components of the landscape equation (Landscape = Abiotic components + Biotic components + Cultural components), specifically for the sagebrush landscape.

**Specific Lesson Language Objectives:** *Students will be able to…*
- Understand the meaning of abiotic, biotic, culture, and landscape.

**Key Vocabulary Words:**
- Landscape
- Ecosystem
- Abiotic
- Biotic
- Culture
- Interdependent

**Background Information for the teacher:**
Students will gain knowledge about the interdependent relationships between the abiotic, biotic and cultural components of a landscape in order to lead them to a deeper understanding of an ecosystem as a whole.

**Abiotic components** of a landscape are non-living chemical and physical parts of the environment that affect living organisms and the function of the ecosystem. Some examples are water, soil, light, radiation, temperature, humidity, atmosphere, clouds, snow and periodic disturbances.

**Abiotic factors:**
a. Sunlight: The amount of available sunlight varies from place to place on Earth and within individual ecosystems. Producers, organisms that can produce their own food, rely on sunlight to photosynthesize.

b. Geology: The study of geology varies widely from place to place. For example, soil can be coarse sand on beaches and deserts or fine clay in riverbanks and marshes. The shape of the land, or topography, also helps to determine the makeup and water availability of any ecosystem.

c. Water: Availability of water directly affects the organisms of an ecosystem. The biological diversity of an area is dependent on the presence of water. Organisms depend on different amounts of water to survive and must adapt to what is available.

d. Temperature: Varies widely between ecosystems and changes seasonally within an ecosystem. The majority of organisms are unable to maintain an internal temperature more than a few degrees above or below the surrounding temperature. This limits where different species can be found.

e. Wind: The driving force behind weather patterns; it shapes ecosystems daily through seed dispersal, shifting substrate, and storm damage. It also aids evaporation and is a constant threat of desiccation to terrestrial organisms.

f. Periodic disturbances: Most ecosystems undergo periodic disturbances that interrupt the “normal” functioning of the ecosystem. As an example, forests can have disturbances like floods, fires, or short-term drought. These disturbances happen frequently enough that species have developed adaptations, which help them survive or take advantage of the disruption. In many cases, organisms rely on disturbances for their survival, such as Lodge pole pines, whose serotinous cones rely on the heat of the fire to open. (Schutsky, Kaufman, & Signell, 2006)

Biotic components of a landscape include everything that is living, was once living, or derived from something that is living. Examples are mammals, birds, reptiles, plants, decomposers, insects, scat, wood, etc.

Biotic factors:
Organisms, adapted to living within certain ecosystems, engage in competition for resources like water, sunlight, space, food and nutrients. They often engage in actions that are mutually beneficial to each species. The most important ecological distinction between organisms is how they get their nutrients. Organisms get their nutrients in three basic ways: the producers through photosynthesis, consumers through ingestions, and decomposers through absorption. (Schutsky, Kaufman, & Signell, 2006)

Cultural components of a landscape include anything that was human made or in any way that humans influenced the landscape. Examples are telephone poles or wires, fences, roads, hiking or hunting trails, dams, petroglyphs, etc. These components may have once been a biotic factor such as a wooden fence post but have been changed and manipulated to meet the needs of humans. Humans have been changing and manipulating the landscape since we arrived in North America through hunting, gathering, agriculture, and construction. In more recent years we have had an even bigger impact on the landscapes that surround us through our infrastructures. They are included and important in the landscape equation because humans have such a large influence on ecosystems. It is important to recognize and understand these components and the impacts they play because, as humans, we are also an intricate part of the landscape and the interdependent relationships that exist within that ecosystem.

Examples specific to Sagebrush:
Abiotic: Soil, rocks, clouds, water in the soil, temperature, etc.
Biotic: Sage grouse, pronghorn, beetles, ants, western meadowlark, sagebrush lizard, grey fox, Indian paintbrush, Bitter brush, Rabbit brush, Mountain Big Sage, mushrooms, etc.
Culture: fences from ranches, telephone poles, oil pads, roads, trails, crops, ancient ruins, petroglyphs etc.

Building Background for Students: (ELL principle)
Activate Prior Experiences:

The teacher will explain that students will do the following:
1. Closely examine what makes up the sagebrush ecosystem.
2. Explain that before today’s activity there will be a brainstorming activity of things that might be found in the sagebrush ecosystem by creating a concept map chart on a large piece of paper.
3. Prior to the brainstorming activity ask, “Can anyone share a story of a time you spend in this community?”
4. Have 2-3 students share an experience they had in the sagebrush community.
5. Give each student a few post-it notes and ask them to write or draw a picture of things they believe they could find in the sagebrush ecosystem.
6. Students will place their post it notes on the poster that says “sagebrush ecosystem.”
7. Students share what they wrote or draw to help all students gain a better understanding of what can be found in this community.

**Link to New Learning from Prior Learning:**
The teacher will explain to students that they will:
1. Engage in an activity that will help categorize things that can be found in the sagebrush ecosystem.
2. Work in pairs to explore various pictures and objects that are placed around the room. Their job is to make observations and think of ways in which they could group these pictures and objects. This activity will lead students towards categorizing their findings into the landscape equation that is composed of abiotic, biotic, and cultural factors.
3. Compare the pictures and objects in the room to what they have put on the sagebrush ecosystem chart.
4. Add any new ideas to the chart, thinking about whether this object is living, non-living, or human related.

**Vocabulary:**
The teacher will:
1. Explain that words will be added throughout the unit and that students should consult the wall. For this lesson the words abiotic, biotic, culture, and landscape will be added.
2. Pictures and objects placed around the room will include its name written out for students who may not recognize the object. These words should be written in the native language to assist ELL students.

**Common Student Misconceptions/Student Challenges:**
- Not everything in an ecosystem is connected to one another
- Humans are not part of the landscape model

**Materials:**
- Abiotic objects or pictures
- Biotic objects or pictures
- Cultural objects or pictures
- L = A + B + C sign
- Large piece of paper for list
- “The Sagebrush Sea” documentary

**Set-up:**
- Collect objects that represent abiotic, biotic and cultural components of the equation.
- Set these up around the room or outside space
- Have a place to write the initial list (poster paper or white board)
- Have L=A+B+C written on a large piece of paper that is ready at hand after students come up with the equation.
- Have access to the “Sagebrush Sea” documentary.

**Lesson Agenda**

<table>
<thead>
<tr>
<th>Review: Approximately 10min</th>
<th>Suggested Procedure (step-by-step)</th>
<th>ELL Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have students think of at least two things they remember about how maps can help us better understand our local community.</td>
<td></td>
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<tr>
<td>Pose the following questions:</td>
<td></td>
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<tr>
<td>o “What can maps teach us? How can we use maps to help us better understand our local community?”</td>
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<tr>
<td>o Have students share their ideas with the person sitting next to</td>
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<tr>
<td>Naming two things they remember helps students recall information. This helps increase</td>
<td></td>
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</tbody>
</table>
| Brainstorm about Sagebrush Ecosystem | Watch a clip from “Sagebrush Sea” | thinking.  
|-----------------------------------|---------------------------------|--------------------------------------------------------|
| • Remind students that: “yesterday we took a look at our personal community and then looked at the community of Wyoming through different maps on WyoBio. Today we are going to think about our natural community.” | • Pose the following question:  
  ▪ “What ecosystem is most dominant here in our community?” (Sagebrush Ecosystem). | • Small group work will increase interaction.  
• Lower ELL students can list or draw what they might find in the sagebrush ecosystem.  
• Brainstorming helps to increase thinking and activate prior knowledge.  
• Watching a film will help increase comprehensibility.  
• Making additions to original brainstorm will help link prior knowledge to new learning. |
| • Have students work in a small group to create a list of what we might observe and find in the sagebrush ecosystem. | • Have students write this brainstorm list in their naturalist journals. |  
• Probes if students are struggling:  
  ▪ “What birds, insects, plants, or signs of humans might we observe in the sagebrush? What kind of weather might we experience?” |  
• Ask students to write down their brainstorm on a big piece of paper provided. (D1) |  
Sagebrush Sea:  
• Explain to students that they will watch the introduction clip from “The Sagebrush Sea” |  
• Explain that students will need to record what observations of what lives in the sagebrush ecosystem according to what they see in the film. Students will record their observations in their naturalist journals. |  
• After movie clip, ask students to make additions to the original list. |
| Explore:  
Approximately 30min | Students will categorize pictures and objects based on observations |  
• Have students work in pairs or small groups to explore various objects and pictures that are placed around the room. |  
• Small group and pair group increases interaction.  
• Classifying and categorizing and describing increases higher order thinking. |
|  
  o Students will walk around and make observations about the objects and pictures.  
  o Pose the following questions: “What are these things? What do they have in common?” |  
  o Potential student responses: (will name the picture or object. The rabbit, mouse, and deer all have fur)  
  o Pause students and have them talk about what they are observing. |  
  
|  
• Small group and pair group increases interaction.  
• Classifying and categorizing and describing increases higher order thinking. |
- Ask students if they have any questions?
  - Have peers help to answer these questions first.

- Have students walk around the room again, and this time direct students to decide how they would group or categorize some of these pictures and objects.
  - Have them write these thoughts in their naturalist journal? (D2)

- As an entire class, discuss their category and group choices. Have students physically place the objects and pictures into these various groups and discuss why they placed them into a particular group.

- Pose following questions:
  - “Does anyone agree or disagree? Why or why not?”
  - Compare the groups. “What are some similarities and differences you notice between the groups? Could any objects be in multiple groups?”
  - Potential student responses: (This group has animals with fur, which is similar to the group over there. However, this group contains objects that these animals would eat, such as plants.)
    - Emphasize some of the living and nonliving objects because this will help them later with the landscape equation. Also encourage them to point out objects that are connected to humans (fence, petroglyph, crops, etc.)

**Explain: (next day)**
Approximately 20-30min

**Student development of the landscape equation**

- Explain to students that they will be learning a model today that is in the form of an equation.
  - Emphasize that models are important because they help us to simplify complex ideas, such as understanding the interdependent relationships that exist in an ecosystem. Models can be both explanatory and predictive. In this case, the landscape equation model is an explanatory model that helps us to explain how all the components that are found within an ecosystem are connected.
    - For example: The landscape model explains that a landscape is composed, or made up of, abiotic parts, biotic parts, and cultural or human influenced parts. When we put them all together and begin to think about how they are all connected, we can begin to gain a picture of how all the pieces of this landscape or ecosystem are connected to one another.

- Write on the board or have equation written on a large piece of paper

**Students’ asking other students before asking a teacher helps to increase interaction.**

**Pictures and objects will include names in both English and native language to help with new vocabulary.**

- Constructing a model based on observations that students made helps to increase higher order thinking.

- Learning new and key vocabulary in context. These new words can be added to the word wall.
(L = A + B + C).

• Pose following questions:
  o “What do you think this equation means?”
  o “What parts of the equation do you recognize?” “What parts do you not recognize?”
    ▪ Have students guess what they think the letters stand for.

• Go back to the groups they created earlier. Emphasize the nonliving and living groups.
  o Pose the following questions:
    ▪ “What connections do you see that could link these two groups together?”
    ▪ Potential student responses: (Water and plants, sagebrush and sage grouse, air and plants, etc.)
  o Explain that scientists use specific vocabulary to describe these living and nonliving components of a landscape (Abiotic and Biotic).
  o Ask student what they think the “C” could stand for in the equation.
    ▪ Have them share with an elbow buddy before sharing with the entire class?
    ▪ Guide students to think about the human related objects and pictures from earlier.
    ▪ Pose the following questions:
      • “How do you think humans are a part of the landscape?”
      • Lead them to C= culture in the landscape equation.

  o It is important that students reach these conclusions without being told by instructor. You can guide them and give them the tools needed to discover the meaning on their own.

• Once students understand what each part of the equation means ask them, “Why do you think these three components or parts make up a landscape?
  o Potential Student Responses: (They are all related; plants need sunlight and water to grow, rabbits rely on these plants for food, and humans might hunt these rabbits to feed to their families.)
<table>
<thead>
<tr>
<th>Elaborate: Approximately 30-45min</th>
<th>Revisit Pictures and Objects:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revisit pictures and objects to sort them according to the landscape model</td>
<td>Focus students’ attention on the pictures and objects around the classroom again.</td>
</tr>
<tr>
<td>Brainstorm and discuss connections between the three components of the model</td>
<td>Pose the following question:</td>
</tr>
<tr>
<td>Think about how the landscape equation connects to the idea of place and community</td>
<td>o “If we are thinking about the landscape equation, how could we group these objects into the three components of the equation?”</td>
</tr>
<tr>
<td>Reflection Activity</td>
<td>o Possible student responses: (We could put them into non-living, living, and human influenced groups)</td>
</tr>
<tr>
<td>Ticket out to see what students understood about the lesson</td>
<td>Find connections among the three groups:</td>
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<tr>
<td></td>
<td>Have students pick two or three items from the pictures and objects around the room to create a model that demonstrates the relationships in the Landscape Equation. (F1)</td>
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<tr>
<td></td>
<td>Ask students, “What connections exist to link these items together?”</td>
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<td></td>
<td>Have students write or draw the example in their naturalist journal.</td>
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<tr>
<td></td>
<td>o They must be able to explain their reasoning for these connections between the items they chose (Ex. plants need water and air and humans need plants to eat); label each item abiotic, biotic, or culture.</td>
</tr>
<tr>
<td>Connecting Landscape Equation to Place:</td>
<td>Pose the following questions:</td>
</tr>
<tr>
<td></td>
<td>o “Which objects might we find in the sagebrush ecosystem?”</td>
</tr>
<tr>
<td></td>
<td>o “Does this match our original list?” “Which objects had we not included in the original list?”</td>
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<td></td>
<td>o “Why do you think we may have forgotten these objects?”</td>
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<tr>
<td>Reflection:</td>
<td>Have students point out the pictures and objects that are around the room that they believe might exist in the sagebrush landscape.</td>
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<tr>
<td></td>
<td>Have students add these objects to the original list of what exists in a sagebrush landscape. (F2)</td>
</tr>
</tbody>
</table>

- Real pictures and objects increase comprehensibility
- Learning vocabulary in context through placing new words with actual pictures and objects.
- Discussing connections among three groups increases higher order thinking through comprehension.
- Constructing a model encourages students to synthesize what they have learned about the landscape equation.
- Connecting the landscape equation to place increases higher order thinking through the process of
- Inform students that they need to write 3-4 complete sentences for this reflection.
- “Do our cultural objects have positive and negative impacts on the sagebrush landscape?” “Or do they not have any impact at all?”
- Pick an object or picture in the room and record your thoughts on the impact it may have on the sagebrush ecosystem?
- Pick and object or picture in the room and record what impact it could have on our community? (S1) Could be one of their graded reflections for the naturalist journal assignment.

**Ticket out:**
- On a piece of scrap paper have students respond to the following questions:
  - What was the big idea of this lesson?
  - Give an example of one abiotic, biotic, and cultural component that can be found in your community.
  - What questions do you still have? (F3)

**Landscape Quilt Activity:** (If time remains or can be done on a field trip day) (S2) A graded assignment based on completion.
- On a field trip to the sagebrush or just outside the school have students draw the landscape they observe before them.
  - Divide a piece of paper in their journal into four quadrants. In one quadrant they will draw any abiotic components they see, in the second quadrant they will draw any biotic components they see, in the third quadrant they will draw any human made cultural components, and in the fourth quadrant they will draw the whole landscape with all three components present.
  - Have them share their landscape drawings with a peer to compare and contrast?

Have students do a landscape quilt at school and one in the sagebrush and then have them compare and contrast their quilts. What are the differences? What are the similarities? What components are more prevalent in the quilt near their school?

**Evaluations and Assessment Check ins:**
- **D**: Diagnostic assessment
- **F**: Formative

(D1): Activity that will help instructor understand student’s prior knowledge of what can be found in the sagebrush ecosystem.

(D2): A diagnostic of students’ conceptions of how organisms and human created artifacts are related and connected.

(F1): A creative assignment that allows students to use what they have learned through the creation of a model that shows the parts of the landscape model

- Reflection increases interaction as students are given time to think independently or with a peer about what they have just learned.
- Allowing lower level ELLs to draw instead of write allows them to share the content they have learned without the lack of language getting in the way.
- The landscape quilt activity increases higher order thinking through application of the components of the landscape equation.

- Assessments will increase interaction, comprehensibility, and higher order...
<table>
<thead>
<tr>
<th>assessment</th>
<th>and how these parts are connected. (F2): Students will come back to original list to add additional layers based on what they have learned throughout the lesson. (F3): An informative assessment for instructor to see if students captured the main idea of the lesson, to show what they have learned, and to ask any questions they still do not understand. (S1): Assesses what students have learned about the impact that humans can have on a landscape and how we are ultimately connected to that landscape through the practice of reflection. (S2): A fun and creative way for students to put what they have learned into practice by applying the landscape equation to their own place and landscape.</th>
</tr>
</thead>
<tbody>
<tr>
<td>S: Summative assessment</td>
<td>thinking.</td>
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<tr>
<td></td>
<td>• Journal assessments can be modified according to students’ ELL level through creating a list, drawing or pointing to oral descriptions.</td>
</tr>
</tbody>
</table>

**References:**
Lesson 3: The Importance of Air and Water to the Sagebrush

Unit: 5th Grade Ecology Unit: A Sagebrush Expedition
Lesson: The Importance of Air and Water to the Sage

Overview: The objective of this lesson is to explore some of the abiotic factors that influence the sagebrush landscape. Students will review what they learned from the landscape equation through a fun game of Simon Says. They will think about why plants rely chiefly on air and water to create their own food in order to grow. The emphasis will be on the idea that plant matter comes mostly from air and water not from soil. Through inquiry, students will design a mini research investigation that explores deeper into the relationship between these abiotic factors and plants, which allows students the opportunity to witness how matter can be transported into, out of and within a system.

Main Take Away: Students will learn that plants do not produce the food they need to grow from the soil. Instead plants get what they need to grow chiefly from air and water.

Learner Outcomes

Students will be able to...

- Explain why air and water are considered abiotic factors in the sagebrush landscape.
- Understand how and why plants acquire their material for growth chiefly from air and water.
- Engage in scientific investigations that give them the opportunity to support an argument with evidence, data, and/or a model.

Getting Ready

Materials: pictures for abiotic Simon Says game, sagebrush list, probe worksheets, materials for mini SCI (mini scientific investigation); (bean seeds, plastic zip lock bags, water, paper towels, soil, cups for planting with soil, salt, sugar, ruler, magnifying glass, etc.), naturalist journals, pencils, example table.

Preparation: Gather abiotic pictures and/or objects from previous lesson for the Simon Says game. Gather all possible materials for mini SCI. Collect more materials than you think you might need in order to give students the opportunity to choose how they want to manipulate a variable in growing their bean seed.

Location: Outside for Abiotic Simon Says. Classroom for remainder of the lesson.

Length of Time:
2-3 Lessons
Approximately 60-75 minutes each

NGSS Standard(s) Addressed: 5th grade Life Science 1: From Molecules to organisms: Structures and Processes

- Performance Expectations: 5-LS1-1:
  Students who demonstrate understanding can: support an argument that plants get the materials they need for growth chiefly from air and water. (emphasis on the idea that plant matter comes mostly from air and water not from soil)
- Disciplinary Core Ideas: LS1. C:
  Organization for Matter and Energy Flow in Organisms: plants acquire their material for growth chiefly from air

Place-Based Principle(s) Addressed:

- Learning takes place in the schoolyard, local community, and local environment.
- Engaging students in investigation, inquiry, and problem solving.
- Using local experts
and water.

- **Cross Cutting Concepts: 5-LS1-1:**
  Energy and Matter: Matter is transported into, out of and within systems.

- **Science and Engineering Practices: 5-LS1-1:**
  Engaging in argument from evidence: **support an argument with evidence, data, or a model.**

- **Connections to Nature of Science: 5-LS2-1:**
  Scientific knowledge is based on empirical evidence

### Unit Connections

(How specific lesson connects to overall goals and objectives of the unit)

### Transfer Goals for Lesson: *Students will be able to independently use their learning to understand that…*

- **TG1** - Science is a process that helps us gain a collective understanding of how the world works, it is a lifelong process, it is applicable every day, and accessible to everyone.
- **TG2** - Humans are an interconnected part of the natural world and can have both positive and negative impacts.
- **TG3** - Cultivating a sense of place, through intentional interactions, inspires curiosity about one’s community and helps to develop a conservation ethic.

### Unit Essential Question: *Students will keep considering…*

What is special about my community and what can I learn from it?

### Specific Lesson Content Objectives: *students will be able to…*

- Explain why air and water are considered abiotic factors in the sagebrush landscape.
- Understand how and why plants acquire their material for growth chiefly from air and water.
- Engage in scientific investigations that give them the opportunity to support an argument with evidence, data, and/or a model.

### Specific Lesson Language Objectives: *Students will be able to…*

- Define and provide examples of the terms observation, question, hypothesis, data, results, and conclusion in the context of the steps of the science circle.
- Orally engage in a scientific argument by pointing, speaking, or a combination of both.

### Key Vocabulary Words:

- Water
- Air
- Photosynthesis
- Observation, question, hypothesis, data, results, conclusion
- Food vs. Nutrients

### Background Information for the teacher:

Students will be introduced to the science circle, which helps to explain the scientific process of investigation. Through the investigations and exploration of how plants use water and air chiefly to grow, students will gain knowledge and awareness of these abiotic components that are specific to the sagebrush ecosystem. This will give them a deeper understanding of this piece of the landscape equation and how these abiotic factors affect the flora and fauna of the sagebrush landscape.

### The Science Circle:

A tool used by educators to help explain the process of scientific investigations. It breaks down the process of research into various steps. These steps used by researchers when performing research. The steps include the following:
1. **Making Observations:** Students are encouraged to look at the world around them and asked to begin noticing things around them based on the use of their senses. It is important to encourage the use of all of our senses; especially since we do not commonly use taste. We talk about how, as humans, we tend to rely heavily on our sense of sight, but in fact we have many other senses that when used allow us the opportunity to connect with the world around us at a much deeper level. Discuss what senses other animals use or rely on more heavily. Examples: coyote uses sense of smell, owls use sight but specifically night vision, raccoons use their sense of touch, and rabbits use their sense of hearing.

2. **Asking Questions:** After observations have been made begin to ask questions. Why does a coyote rely heavily on their sense of smell, how can sage survive with very little water available, why do pronghorn migrate so far in the winter time? The idea is to get students to ask questions and hone in on their curiosity about the environment around them.

3. **Making a Hypothesis:** Hypotheses are a supposition or proposed explanation made on the basis of limited evidence as a starting point for further investigation that drive research. A person observes something in the environment around them, which sparks their curiosity and causes them to ask a question. That person then predicts the answer to the questions based on prior knowledge and evidence surrounding them. However, in order to prove or disprove this prediction or hypothesis that person must investigate. For example, a student observes a Western Meadowlark bird while out in the sage and questions why some are extremely yellow and some appear to be just brown. That student then creates a hypothesis; the birds that are really yellow are trying to get the attention of other birds. The question is, “How can I figure out whether or not I am correct?”

4. **Design a Study:** One then decides determines the process to prove or disprove their hypotheses. One might go out in the field to look at more birds, look in books, journals or on the internet; or possibly use another scientific method, which assists in the collection of data needed for the research project.

5. **Collect Data:** Go get our hands dirty. Students need to collect data or information based on the question. For the example given above, going out in the field to observe the behavior of these birds further would be a useful endeavor. Students can research books, journals, or the internet to find out more information about the behavior of this bird species.

6. **Analyze Data:** When the data has been collected, it needs to make sense. Using tables, graphs, or other statistical methods would be beneficial. What does the data tell us? What are our results?

7. **Conclusion:** Finally, drawing conclusions based on the collected data will help to answer the question and determine whether or not our hypothesis was supported. We discovered that male birds are usually trying to attract females for mating during the spring months and become extremely bright and vocal. When students go out in the field and witness this behavior happening with the Western Meadowlark, it now can be concluded that the birds that are bright yellow are males and they are trying to get the attention of the females.

8. **Share:** This can arguably be the most important part of the science circle. What is the point of performing investigations and doing research if the information is not shared? The information that we currently have about various ecosystems has come from others research. (Teton Science Schools, 2016)

By understanding the steps in the science circle, students can understand how to perform scientific investigations based on their curiosity about the world around them. The overall objective is for students to make observations, ask questions based on their curiosity and help them understand that anyone can do science and anyone can be a scientist anywhere.

**Photosynthesis:**
The process used by plants and other organisms to convert light energy, normally from the Sun, into chemical energy that can be later released to fuel the organisms’ activities or energy transformation. During oxygenic photosynthesis, light energy transfers electrons from water (H2O) to carbon dioxide (CO2), which produces carbohydrates or sugars, which are
the food for the plant. In this transfer, the CO2 is “reduced” as it receives electrons, and the water becomes “oxidized”, as it loses electrons. Ultimately plants are sequestering CO2 from the atmosphere and giving off the left over O2 after they have made food for them to grow. The CO2 is coming from the atmosphere and the H2O is providing the electrons for photosynthesis to occur.

Food vs. Nutrients plants need:
Plants need nutrients to survive and grow such as phosphorus, nitrogen, potassium, sulfur, calcium, oxygen and magnesium. Many of these other nutrients can be found in soil. These nutrients are not necessary for the plant to create food, but are vital for the mature growth of the plant. It is important to recognize that soils do not need soil to grow food, but soil often contains many of the other nutrients that the plant needs. If the nutrients are provided, the plant does not need soil in order to survive. This can be seen through hydroponics. The word hydroponic comes from the Latin word meaning working water. Simply put, it is the art of growing plants without soil. The plants are able to get the nutrients they need for photosynthesis from the air and sunlight. The remaining nutrients are available to the plants through the water.

See Life Science Assessment probes 13 “Needs to Seeds” and 15 “Is it Food for Plants” for more information regarding where plants and seeds get their nutrients in order to make their own food to survive and grow.

Building Background for Students: (ELL principle)
Activate Prior Experiences:
The teacher will hand out the “Is it Food for Plants” probe worksheet that will ask students to pick from a variety of options what might be food for a plant. This exercise will help access students’ prior knowledge on how plants grow and what they use for food. Students will work individually to mark which things they think is food for plants.
The teacher will ask students to:
1. Turn to a peer sitting next to them to discuss what they chose.
2. Explain why they chose these things as food for plants.
3. Share their thoughts with the rest of the class and write these choices on the board for all students to see.

Link to New Learning from Prior Learning:
The students will be introduced to the scientific process through a visual representation called the science circle. They will be introduced to the eight steps of the science circle in order to prepare them for the mini scientific investigation they will afterwards perform.
The teacher, working together with students, will introduce each step and ask students to:
1. Think about the meaning of these words: observation, question, hypothesis, collecting data, results, conclusion, and share.
2. Create kinesthetic movements for each step in order to help students remember each steps and its meaning.
   For example, students might pretend to look through binoculars to demonstrate the observation step of the science circle.

Vocabulary:
New content vocabulary, observation, question, hypothesis, data, results, conclusion, nutrients, photosynthesis, will be added to the word wall.
The students will participate in the fly swatter game. The class will be divided into two groups and the teacher will do the following:
1. Write the vocabulary words on the board.
2. Call out a statement or perform a kinesthetic movement
   Students will have to announce the correct word before the other team.
   An example is “what is the process called that helps plants make their own food?”
   Students would need to call out the word “photosynthesis”.
   Another example might be that the teacher pretends to look through binoculars and students need to hit the word “observation”.

**Common Student Misconceptions/Student Challenges:**
- Plants require the material and nutrients they need to grow through the soil.
- The difference between food and nutrients
- Concept that animals get their food and nutrients from the environment around them where plants get their nutrients from the environment around them to create their own food.
- All plants need light
  - This is true for part of their life cycle, but a plant embryo, a sprout, and an emerging seedling do not need light at those stages in the life cycle because they have stored energy and therefore do not need to make food. Once it has used up all the food that was stored in the seed’s cotyledon, the seedling needs light to make its own food, using its true leaves.

**Materials:**
- Pictures for abiotic Simon S
- Sagebrush list from previous lesson
- Materials for mini SCI (bean seeds, soil, plastic zip lock bags, paper towels, water, sugar, salt, cups for planting with soil, ruler, magnifying glass, etc.)
- Naturalist journals and pencils

**Set-up:**
- Gather abiotic pictures and/or objects from previous lesson for Simon Says game.
- Gather all possible materials for mini SCI.
- Collect more materials than you think you might need in order to give students the opportunity to choose how they want to manipulate a variable in growing their bean seed.

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<tr>
<th>Lesson Agenda</th>
<th>Suggested Procedure</th>
<th>ELL Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review: Approximately 15min</td>
<td>Class will begin by assessing students about what they learned the previous lesson.</td>
<td>• Reviewing and using repeating both information and vocabulary increases comprehensibility.</td>
</tr>
<tr>
<td>Engage: Approximately 20min</td>
<td><strong>Abiotic Simon Says:</strong> Approximately 5min</td>
<td>• Interactive game will reinforce new vocabulary, increase interaction, and increase comprehensibility by connecting to prior knowledge.</td>
</tr>
<tr>
<td>Abiotic Simon says game will get students thinking about Abiotic factors in the landscape</td>
<td>• Review with students the components of the landscape equation that they learned previously. (Abiotic= nonliving, Biotic= living, Culture= human influences) Explain to class that the focus for today’s lesson will be on some of the abiotic components found in the sagebrush landscape.</td>
<td></td>
</tr>
<tr>
<td>Discussion of abiotic factors specific to the sagebrush landscape</td>
<td>• Students will be asked to perform the action called out by the instructor only if the action involves something abiotic. (F1) For example, if the instructor calls out “Simon Says…pick up soil,” the student must pick up soil or a picture of soil. If the instructor calls out “Simon Says…touch a tree,” “any student who moves towards a tree or picture of a tree is out for that round, because the tree is not abiotic; it is biotic.</td>
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<tr>
<td></td>
<td>• Repeat the step above using various living, non-living, and human (cultural) related objects until you feel that students are able to demonstrate their understanding between these three factors.</td>
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<tr>
<td></td>
<td>o <strong>Possible Abiotic Simon Says Call Outs:</strong></td>
<td></td>
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<tr>
<td></td>
<td>• Pick up soil (abiotic)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Circling</td>
<td></td>
</tr>
</tbody>
</table>
- Find a rock (abiotic)
- Point to a piece of scat (biotic)
- Point to the sun (abiotic)
- Breathe in the air (abiotic)
- Hug a tree (biotic)
- Pat a friend’s back (biotic)
- Flap your arm’s like a bird (biotic)
- Touch something human made (culture)
- Hike down a human made path (culture)

**Introduction to Abiotic Factors in the Sage:** Approximately 5min

- Pose the following question: “Looking at our list from the previous lesson, which objects would be considered abiotic? Please explain why.”
  - **Potential Student response:**
    - These things are non-living
  - Ask students to volunteer to circle an abiotic factor in a different color marker. *(F2)*
  - After each student circles have student ask peers whether they agree or disagree with this decision and explain their answer.

- Introduce that they are going to focus on the abiotic factors of water and air:

- Ask students to think of how some of the biotic factors are interconnected to the abiotic factors of air and water with an elbow buddy. Share out to the whole class.
  - **Potential Student responses:**
    - Plants need water to grow
    - Plants make their food through photosynthesis
    - Plants make their food using the light from the sun
    - Animals need water to drink
  - The lesson focus should be the student responses about plants needing water or air to survive.

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**Explore:**
Approximately 30min

**Is it Food for Plants Probe:** Approximately 15min?

- Hand out “Is it Food for Plants” probe worksheet.
- Have one student read the instructions.

- Elbow buddies will increase interaction.
- Probes will...
plants probe will get students thinking about what plants need to grow.

Needs of seeds is an extension probe. Can be used instead of the first probe or as an addition
Approximately 30min

• Give students a few minutes to put an X next to things they think plants use as food. Make sure students explain their thinking by 2-3 bulleted responses and at least one complete sentence.
• Have students share what they thought with an elbow buddy.
• Discuss results with the class as a whole.
• **Purpose of probe:**
  - The purpose of this assessment probe is to elicit students’ ideas about food and plants. The probe is designed to reveal whether students use a biological concept of food to identify what plants use for food.
  - *See attached probe for further explanation*
• Pose the following question:
  - “What is food and what is a nutrient?” *(D1)*
  - Have them discuss this in small groups?
• Write the words food and nutrient on the board and ask students to come up and write some of their thoughts around these words.
  - **Potential Student response:**
    - *Food is what I ate for breakfast*
    - *Nutrients are in my vitamins*
    - *Food is something you cook*
    - *Nutrients are what plants need to grow*
• Discuss these responses and help students understand the differences between the word *food* and the word *nutrient*.
  - Emphasize that animals, including humans, must find their food versus plants use nutrients to create their own food in the form of sugar.
• Show a container of plant food and a container of human vitamins. Explain the analogy between the two to show that their purpose is to provide essential inorganic nutrients, not food energy.
  - Pose following question: “Can humans survive on only these vitamins?” Why or why not?
  - Have students think and pair, share (think individually, pair up to discuss, and share with whole group)

**Needs of Seeds Probe:** Approximately 15min
• Pose the following question: “Now that we have learned a little more about what nutrients plants need in order to create their own
food, let’s think about what a seed would need in order to germinate or sprout.”

- Hand out “Needs of Seeds” probe worksheet.
  - This probe can also be used as a card sort. Write the words on cards and have students sort them into piles of things seeds need to sprout and things seeds do not need to sprout. Listen carefully as they discuss their ideas about which pile to put their cards in.
  - Have a picture of a sprout or a real sprout for students who may not know this word or what a sprout is. (F3)

- Have one student read the instructions.
- Give student a few minutes to put an X next to things they think plants use as food. Make sure students explain their thinking by 2-3 bulleted responses and at least one complete sentence.
- Have students share their thoughts with an elbow buddy.
- Discuss results with the class.
- **Purpose of probe:**
  - The purpose of this assessment probe is to elicit student’s ideas about seeds. It specifically examines whether or not students recognize that a seed has needs similar to other organisms that allow it to develop into the next stage of its life cycle.
  - See attached probe for further explanation

- Explain to students that they are going to engage in a mini science investigation where they will be given the opportunity to make predictions and test their ideas with seeds that germinate easily, such as bean seeds.

### Explore: Approximately 30min

**Introduction to the Science Circle: a model for the scientific process**

- **Introduce the Science Circle:** Approximately 15min
  - Bring out science circle poster that includes the eight steps. (see background information for each step’s description)
  - Explain that the Science Circle is a model to help represent the scientific process used by researchers and scientists.
  - Number students from 1-8. Each number group will represent one of the steps of the science circle.
  - Objective of each group: Responses should be written or drawn in naturalist journal (D2)
    - Discuss what the word means
    - Why is this included in the scientific process?

- Small group work will increase interaction.
- Students will explain what they think the steps of the science circle mean. This will activate prior knowledge, introduce new vocabulary, and increase higher order thinking
| Elaborate: Approximately 45-60min | **Mini Science Investigation:** (Mini SCI) (S2) Approximately 20min (S1) Investigations that involve germinating seeds under various conditions help students recognize that some factors are needed for germination and others are not. Students can eventually distinguish between the needs of seeds and the needs of the growing plant.  
- Announce the following to students: “Now that we have a better understanding that plants need nutrients from both air and water in order to create their own food, you are going to have the opportunity to get involved in an inquiry-based mini science investigation using steps from the science circle.”  
- Have students work in pairs for this investigation.  
- Explain that they will be making predictions and will test their ideas using seeds that are easy to germinate or sprout.  
- Once students are in pairs pass out the bean seeds and magnifying lenses for students to make initial observations.  
  - Students need to draw their bean seed in their naturalist journal and write 2-3 descriptions about the bean seed.  
  - Help students see where water is taken in, gases are exchanged, and food is stored for the young embryo. This will help students understand how the seed contributes to the growth and life functions of the young plant.  
- Have students think about a question they would like to ask that involves germinating their seeds under various conditions. This will help students recognize that which factors are needed or not for germination.  
  - Potential questions:  
    - *Does a bean seed need soil to grow?*  
    - *Will a bean seed grow better in the light or in the dark?*  
    - *Will a bean seed sprout earlier outside or inside*  

|   | How does this stage help with a person’s research or investigation?  
|   | What other steps might your step be connected to? Give evidence and reason to back this claim.  
- Have each group share. Encourage creativity in the presentation. For example, students could orally present as well as act out their step. (One student could talk about observation, while other students in groups are acting out what that might look like).  
- It is important to emphasize that all students in each group need to be a part of the presentation.  

|   | Students will create kinesthetic movements for each step of the science circle model, which will increase comprehensibility and interaction.  
|   | This hands-on, inquiry based experiential investigation will increase interaction and comprehensibility.  
|   | Working in pairs will increase interaction. ELLs can be placed with higher-level ELLs or native English speakers.  
|   | Lower level ELLs can draw each step of the investigation and label drawings with one word if able.  
|   | Modeling will be important for this investigation and will increase through explanation.
• Once students have a question they need to create a hypothesis about what they think will happen to the bean seed.
  
  o Potential hypotheses:
    - A bean seed need soil in order to grow.
    - A bean seed will sprout faster if grown in the light.
    - A bean seed will sprout earlier inside the classroom because it is cold outside.
  
• Now students need to set up their investigation. Have various tools and materials out on a table so students can choose what they need to perform their investigation based on their question and hypothesis. **Students may need guidance with this process. Emphasize that they are only changing one variable or factor (soil, temperature, light, etc.)**
  
  o Potential investigations:
    - Students will plant one bean seed in soil and one bean seed in a bag with wet paper towel and place them in the same spot.
    - Put two bean seeds in wet paper towels in two separate plastic bags.
    - Place one bag in a dark closet and one bag near the window where natural sunlight filters through.
    - Put two bean seeds in wet paper towels in two separate plastic bags and place one bag in the classroom near the window and one bag outside.
  
• Emphasis for this investigation is on students beginning to use the science circle and recognizing which step they are using, changing one variable to see more clearly how plants get the nutrients they need to create their own food, and inquiry.
  
• Students are given the opportunity to create their own investigation with guidance.
  
• See attached probe 5 “Seeds in a Bag” for another investigation idea looking at whether or not seeds can grow if they are in a sealed bag (modeling a closed system).
  
• This will be an ongoing investigation. Students will need to check on their beans each day and record measurement of growth in their naturalist journal. **They will be graded on initial observations and data table at the end of the unit.**
  
  o Display example table (attached below) for students. This will help them know how to set it up in their journals.

**comprehensibility.**

• Higher order thinking will be increased through the investigation. Students will need to explain, construct, compare and contrast, and conclude.

• Students will also need to argue why plants chiefly use air and water to grow using evidence which increase higher order thinking.

• Lower level ELLs can demonstrate their knowledge through drawings, pointing, and basic written conclusions.
They may need additional guidance in setting the table appropriately for their investigation.

<table>
<thead>
<tr>
<th>Evaluations and Assessment Check ins:</th>
<th>Evaluations and Assessment Check ins:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D</strong>: Diagnostic assessment</td>
<td>(F1): Creative way to explore what students have learned and understand about the abiotic, biotic, and cultural components of the landscape equation through a fun game.</td>
</tr>
<tr>
<td><strong>F</strong>: Formative assessment</td>
<td>(F2): Agree and disagree statements provide students the opportunity to practice metacognition by thinking about their own understanding of what an abiotic object is and then applying this knowledge to the sagebrush ecosystem.</td>
</tr>
<tr>
<td><strong>S</strong>: Summative assessment</td>
<td>(D1): Addresses students’ prior knowledge of what food is and what nutrients are in order to understand their conceptions or misconceptions about how they are different and how plants and animals rely on them differently.</td>
</tr>
<tr>
<td></td>
<td>(F3): Card sort assessment of what seeds need to germinate provides an opportunity for students to access their prior knowledge. Additionally, the cards promote metacognition by surfacing uncertainties in their thinking about what seeds really need to grow.</td>
</tr>
<tr>
<td></td>
<td>(D2): Identifies students’ prior knowledge about the scientific process by breaking it into steps. It also displays challenges that exist for students in using this model.</td>
</tr>
<tr>
<td></td>
<td>(S1): Students will be graded on how well they were able to follow the steps of the science circle. Students will be graded on their observation drawing, question, hypothesis, data recorded as plant germinated and grew, and the conclusion they were able draw based on results of their data.</td>
</tr>
</tbody>
</table>

• These assessments will activate prior knowledge, link prior knowledge of abiotic components to new learning about how plants rely on these abiotic components, and increase higher order thinking through using the science circle as a model for the scientific process, which they will demonstrate by engaging in a mini scientific investigation.

References:

- Life Science Assessment Probes 13 and 15.
- TSS Science Circle

Uncovering Student Ideas in Primary Science
Lesson 4: The Dirt on Soil in the Sagebrush

Overview: This lesson aims to have students dig deeper into soil. Although plants rely chiefly on air and water to grow, which they learned in the previous lesson, soil is extremely important for plants as it provides stability, nutrients, and hold water. Students will be given the opportunity to learn about how a local research scientist uses soil to predict the future of the sagebrush ecosystem as they learn how to test and take samples of the soil. They will learn about the different particle sizes in the soil and how this affects water retention, different layers that can be found in soil, and test the pH. They will then be asked to apply this knowledge to continue the story of their local, sagebrush landscape as they work to gain a better understanding of this ecosystem.

Main Take Away: Students will learn the importance of how soil provides stability, nutrients, and holds water for plants. They will focus on how a local research scientist uses soil to predict the future of the sagebrush ecosystem as they learn a variety of methods of how to test and take samples of the soil.

Learner Outcomes

Students will be able to…

- Explain and identify the three particle sizes found in soil (sand, silt, and clay).
- Practice various scientific skills through sampling and testing soil to gain a better understanding of the role soil plays in the landscape.
- Begin to understand how soil type and water availability in the soil can help determine future land management practices through a local Wyoming scientist’s research.

Getting Ready

Materials: plastic bottles, sand, silt and clay samples, water, soil, soil cores, pH kits, example recording sheet, soil horizon diagram, naturalist journals, pencil, and Dr. Kyle Palmquist’s video.

Preparation: Cue video to be shown in the classroom. Beforehand, gather plastic bottles, sand, silt and clay samples, soil cores, soil core sample from different location, soil sample for students to look at, and pH kits. Print out several soil horizon diagrams and example recording sheet. Having soil samples from another location will allow students the opportunity to compare and contrast with soil they sample near school.

Location: Classroom and outside of school. Tests can be repeated on field trip days.

Length of Time:
1-2 Lessons
Approximately 60-75 minutes
Sample skills and tests can be repeated on field trips

NGSS Standard(s) Addressed: 5th grade Life Science 1: From Molecules to organisms: Structures and Processes

- **Science and Engineering Practices: 5-LS1-1:** Engaging in argument from evidence: support an argument with evidence, data, or a model.
- **Connections to Nature of Science: 5-LS2-1:** Scientific knowledge is based on empirical evidence

Place-Based Principle(s) Addressed:

- Using local experts
- Learning takes place in the schoolyard, local community, and local environment.
- Engaging students in inquiry and experiential learning.
**Unit Connections**

*(How specific lesson connects to overall goals and objectives of the unit)*

**Transfer Goals:** *Students will be able to independently use their learning to understand that…*

- **TG1:** Science is a process that helps us gain a collective understanding of how the world works, it is a lifelong process, it is applicable every day, and accessible to everyone.
- **TG2:** Humans are an interconnected part of the natural world and can have both positive and negative impacts.
- **TG3:** Cultivating a sense of place, through intentional interactions, inspires curiosity about one’s community and helps to develop a conservation ethic.

**Unit Essential Question:** *Students will keep considering…*

*What is special about my community and what can I learn from it?*

**Specific Lesson Content Objectives:** *Students will understand and be able to…*

- Explain and identify the three types of soil particles.
- Acquire various skills of testing and sampling soil to gain an overall better understanding of a particular soil and how it plays a role in the overall landscape.
- How soil and water availability in the soil can help determine future land management practices through a local Wyoming scientist’s research.
- Engage in scientific investigations that allow students to support an argument with evidence, data, or a model.

**Specific Lesson Language Objectives:** *Students will be able to…*

- Students will be able to name and describe the three particle sizes of soil (sand, silt, and clay).

**Key Vocabulary Words:**

- Soil
- Evidence
- Argument
- Soil particles (sand, silt, clay)

**Background Information for the teacher:**

**Dirt versus Soil:**

Dirt is what you find under your fingernails. Soil is what you find under your feet. Think of soil as a thin living skin that covers the land. It goes down into the ground just a short way. Even the most fertile topsoil is only a foot or so deep. Soil is more than rock particles. It includes all the living things and the materials they make or change.

**Soil:** A natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment.

The lower boundary that separates soil from the non-soil underneath is most difficult to define. Soil consists of horizons near the Earth's surface that, in contrast to the underlying parent material, have been altered by the interactions of climate, relief, and living organisms over time.

Commonly, soil grades at its lower boundary to hard rock or to earthy materials virtually devoid of animals, roots, or other marks of biological activity. For purposes of classification, the lower boundary of soil is arbitrarily set at 200 cm.

**Ground level:** Plants grow and animals live here. Decomposers recycle dead plants and animals into humus.

**Topsoil:** This sometimes called the organic layer. A thick cover of plants can keep the soil cool and keep it from drying
out. Decomposers recycle dead plants and animals into humus.

**Subsoil**: This is a mix of mineral particles and some humus near the top. Subsoil is very low in organic matter compared to the topsoil. This is the layer where most of the soil's nutrients are found. Deep plant roots come here looking for water. Clays and minerals released up above often accumulate here as water drains down.

**Weathered parent material**: This horizon can be very deep. There's no organic matter here at all. It's all rock particles, full of minerals. The entire soil profile used to look like this all the way to the surface. Physical weathering broke the parent material up into small pieces. This layer may contain rock particles that are different from the bedrock below. A river or a glacier might have brought it from somewhere else.

**Bedrock**: The bedrock formed before the soil above it. It will wait here until erosion or an earthquake exposes it to the surface. Then some of it will be weathered to become the next batch of parent material. The soil-making process will start all over again.

**Soil Forming Factors**

**Parent material**. Few soils weather directly from the underlying rocks. These “residual” soils have the same general chemistry as the original rocks. More commonly, soils form in materials that have moved in from elsewhere. Materials may have moved many miles or only a few feet. One example is glacial till. This is a material ground up and moved by a glacier. The material in which soils form is called “parent material.” In the lower part of the soils, these materials may be relatively unchanged from when they were deposited by moving water, ice, or wind.

Sediments along rivers have different textures, depending on whether the stream moves quickly or slowly. Fast-moving water leaves gravel, rocks, and sand. Slow-moving water and lakes leave fine textured material (clay and silt) when sediments in the water settle out.

**Climate**. Soils vary depending on the climate. Temperature and moisture amounts cause different patterns of weathering and leaching. Wind redistributes sand and other particles especially in arid regions. The amount, intensity, timing, and kind of precipitation influence soil formation. Seasonal and daily changes in temperature affect moisture effectiveness, biological activity, rates of chemical reactions, and kinds of vegetation.

**Topography**. Slope and aspect affect the moisture and temperature of soil. Steep slopes facing the sun are warmer, just like the south-facing side of a house. Steep soils may be eroded and lose their topsoil as they form. Thus, they may be thinner than the more nearly level soils that receive deposits from areas upslope. Deeper, darker colored soils may be expected on the bottomland.

**Biological factors**. Plants, animals, micro-organisms, and humans affect soil formation. Animals and micro-organisms mix soils and form burrows and pores. Plant roots open channels in the soils. Different types of roots have different effects on soils. Grass roots are “fibrous” near the soil surface and easily decompose, adding organic matter. Taproots open pathways through dense layers. Micro-organisms affect chemical exchanges between roots and soil. Humans can mix the soil so extensively that the soil material is again considered parent material.

The native vegetation depends on climate, topography, and biological factors plus many soil factors such as soil density, depth, chemistry, temperature, and moisture. Leaves from plants fall to the surface and decompose on the soil. Organisms decompose these leaves and mix them with the upper part of the soil. Trees and shrubs have large roots that may grow to considerable depths.

**Time**. Time for all these factors to interact with the soil is also a factor. Over time, soils exhibit features that reflect the other forming factors. Soil formation processes are continuous. Recently deposited material, such as the deposition from a flood, exhibits no features from soil development activities. The previous soil surface and underlying horizons become buried. The time clock resets for these soils. Terraces above the active floodplain, while genetically similar to the
floodplain, are older land surfaces and exhibit more development features.

These soil forming factors continue to affect soils even on “stable” landscapes. Materials are deposited on their surface, and materials are blown or washed away from the surface. Additions, removals, and alterations are slow or rapid, depending on climate, landscape position, and biological activity.

When mapping soils, a soil scientist looks for areas with similar soil-forming factors to find similar soils. The colors, texture, structure, and other properties are described. Soils with the same kind of properties are given taxonomic names. A common soil in the Midwest reflects the temperate, humid climate and native prairie vegetation with a thick, nearly black surface layer. This layer is high in organic matter from decomposing grass. It is called a “mollic epipedon.” It is one of several types of surface horizons that we call “epipeds.” Soils in the desert commonly have an “ochric” epipdedon that is light colored and low in organic matter. Subsurface horizons also are used in soil classification. Many forested areas have a subsurface horizon with an accumulation of clay called an “argillic” horizon.

**Soil Layers:**

**O Horizon:** The top, organic layer of soil, made up mostly of leaf litter and humus (decomposed organic matter).

**A Horizon:** The layer called topsoil; it is found below the O horizon and above the E Horizon. Seeds germinate and plant roots grow in this dark-colored layer. It is made up of humus (decomposed organic matter) mixed with mineral particles.

**E Horizon:** The eluviation (leaching) layer is light in color; this layer is beneath the A Horizon and above the B Horizon. It is made up mostly of sand and silt, having lost most of its minerals and clay as water drips through the soil (in the process of eluviation)

**B Horizon:** Also called the subsoil; this layer is beneath the E Horizon and above the C Horizon. It contains clay and mineral deposits (like iron, aluminum oxides, and calcium carbonate) that it receives from layers above it when mineralized water drips from the soil above.

**C Horizon:** Also called regolith: the layer beneath the B Horizon and above the R Horizon. It consists of slightly broken-up bedrock. Plant roots do not penetrate into this layer; very little organic material is found in this layer.

**R Horizon:** The un-weathered rock (bedrock) layer that is beneath all the other layers.

**Measuring Soil pH**

Soil pH provides various clues about soil properties and is easily determined. The most accurate method of determining soil pH is by a pH meter. A second method, which is simple and easy but less accurate then using a pH meter, consists of using certain indicators or dyes.

Many dyes change color with an increase or decrease of pH making it possible to estimate soil pH. In making a pH determination on soil, the sample is saturated with the dye for a few minutes and the color observed. This method is accurate enough for most purposes. Kits (pH) containing the necessary chemicals and color charts are available from garden stores.

There may be considerable variation in the soil pH from one spot in a field or lawn to another. To determine the average soil pH of a field or lawn it is necessary to collect soil from several locations and combine into one sample.

**Descriptive terms commonly associated with certain ranges in soil pH are:**
• **Extremely acid:** < than 4.5; lemon=2.5; vinegar=3.0; stomach acid=2.0; soda=2–4
• **Very strongly acid:** 4.5–5.0; beer=4.5–5.0; tomatoes=4.5
• **Strongly acid:** 5.1–5.5; carrots=5.0; asparagus=5.5; boric acid=5.2; cabbage=5.3
• **Moderately acid:** 5.6–6.0; potatoes=5.6
• **Slightly acid:** 6.1–6.5; salmon=6.2; cow's milk=6.5
• **Neutral:** 6.6–7.3; saliva=6.6–7.3; blood=7.3; shrimp=7.0
• **Slightly alkaline:** 7.4–7.8; eggs=7.6–7.8
• **Moderately alkaline:** 7.9–8.4; sea water=8.2; sodium bicarbonate=8.4
• **Strongly alkaline:** 8.5–9.0; borax=9.0
• **Very strongly alkaline:** > than 9.1; milk of magnesia=10.5, ammonia=11.1; calcium oxide or calcium hydroxide=12

**pH Affects Nutrients, Minerals and Growth**

The effect of soil pH is great on the solubility of minerals or nutrients. Fourteen of the seventeen essential plant nutrients are obtained from the soil. Before plants can use a nutrient it must be dissolved in the soil solution. Most minerals and nutrients are more soluble or available in acid soils than in neutral or slightly alkaline soils.

Phosphorus is never readily soluble in the soil but is most available in soil with a pH range centered on 6.5. Extremely and strongly acid soils (pH 4.0–5.0) can have high concentrations of soluble aluminum, iron and manganese, which may be toxic to the growth of some plants. A pH ranges of approximately 6 to 7 promotes the readiest availability of plant nutrients.

But some plants, such as azaleas, rhododendrons, blueberries, white potatoes and conifer trees, tolerate strong acid soils and grow well. Also, some plants do well only in slightly acid to moderately alkaline soils. However, a slightly alkaline (pH 7.4–7.8) or higher pH soil can cause a problem with the availability of iron to pin oak and a few other trees in Central New York causing chlorosis of the leaves which will put the tree under stress leading to tree decline and eventual mortality.

The soil pH can also influence plant growth by its effect on activity of beneficial microorganisms. Bacteria that decompose soil organic matter are hindered in strong acid soils. This prevents organic matter from breaking down, resulting in an accumulation of organic matter and the tie up of nutrients, particularly nitrogen, that are held in the organic matter.

**Building Background for Students: (ELL principle)**

**Activate Prior Experiences:**
The teacher will have students to the following:
1. Recall what they learned about what plants chiefly need to grow.
2. Think about and then share their thoughts with the other students at their tables.
3. Students will share out what plants need to make their own food.
4. Remember that plants do not make their food from soil, but do receive nutrients from soil.
5. Explain that students will be exploring the importance of soil in the sagebrush ecosystem. Each table will have different soil types on it.
6. Make observations about each example by drawing and writing descriptive words in their naturalist journals and
can work together on this activity.

8. Act out kinesthetic movement they invented from the prior class.
9. Share their observations with the class and descriptive words can be written on the board.
10. Engage in a mini investigation to time how long it takes different soil samples to filter through water.
   Explain that this will help them learn about which soil holds water better and which soil type lets water pass through quickly. Students will work in small groups to perform this task.
11. Finally, students will discuss why one soil type lets water filter through more quickly than the other one.
12. Share their thoughts with the class.
13. Discuss the different particle sizes that can be found in soil, sand, silt and clay. Students will discover that sand is the largest particle size, which is why water filters through it the fastest, and clay is the smallest particle size.

Link to New Learning from Prior Learning:
The teacher will ask students to do the following:
1. Students will go outside and dig up a soil sample near their school. They will be taught how to perform a ribbon test, where they can observe whether or not the soil sticks together.
2. Ask students, “What type of soil particles are present if the soil sample sticks together really well?”
3. Students will think back to the previous investigation to come up with an answer.
4. Discuss their thoughts in pairs and share with the whole group. Students will understand how long it takes this soil sample to filter through water and compare it to the previous soil samples.
5. Make connections and think about whether the soil they dug up outside their school would hold or retain water or let it filter through quickly.

Vocabulary:
The teacher will ask the students to do the following:
1. Draw the three soil particle sizes in their naturalist journals.
2. Label each drawing as either sand, silt or clay. These three words can be added to the word wall.
3. Give a descriptive word and drawing to be placed with the word on the word wall.

Common Student Misconceptions/Student Challenges:
• Soil is uniform throughout all the layer
• Soil provides food for plants to grow.

Materials:
• Plastic bottles
• Sand, silt and clay samples
• Water
• Soil samples from other location
• Soil cores
• pH kits
• Example recording sheet
• Soil horizon diagram
• Naturalist journals and pencil
• Dr. Kyle Palmquist’s video

Set-up:
• Cue video to be shown in the classroom
• Beforehand, gather plastic bottles, sand, silt and clay samples, soil cores, soil core sample from different location, soil sample for students to look at, and pH kits
• Print out several soil horizon diagrams and example recording sheet
• Having soil samples from another location will allow students the opportunity to compare and contrast with soil they sample near school.

Lesson Agenda | Suggested Procedure | Rationale
--- | --- | ---
Review: Approximately 10min | Bean Seed Mini SCI:  • Let students have a few minutes to take a look at their bean seed investigations and record whether or not they have sprouted. | • Review is a strategy used to increase comprehensibility by giving students the
Students will be introduced to the different particles of soil through observations.

Students will make connections through learning from a local scientist.

Give me Five:
- Pose the following:
  - “What is an abiotic factor and how does it play a role in the sagebrush landscape?”
  - Inform students to have a moment to think individually and then you will pick five to share their thoughts.
  - Students can give an example of something that is abiotic as their response. (D1)

Introduce Soil:
- Pass out containers filled with soil to small groups of students.
- Give students a few moments to make observations. Encourage students to make observations based on the following: what the soil looks like, what it smells like, and what it feels like.
- Ask 3-5 students to share their observations. If other students agree with this observation ask them to give a thumbs up, if students disagree with this observation have them give a thumbs down, and if they did not notice this have them give a fist.
  - Ask students who gave a thumbs down to provide reasoning.

University of Wyoming Research Scientist Video:
- Explain to students that many research scientists look at soil in order to gain a better understanding of a particular landscape, such as the sagebrush landscape.
- Pose following question: “What is soil and how can soil help us understand more about a landscape?” Have students think about this and share one idea with a partner. (D2)
  - Potential student responses:
    - Soil is tiny pieces of broken up rock.
    - Soil is used in gardens and is dark colored.
    - Soil determines what type of plants might grow in that landscape.
    - Specific animals might need soil to build their homes.
    - Different types of soil can hold different amounts of water; which plants need to grow.

- Students will be watching a short video about a research scientist from the University of Wyoming. The research looks at how changes in temperatures, precipitation type, and amount of snowpack over time can affect the water availability in the soil, which then influences plants such as sagebrush.

opportunity to summarize and repeat what they learned previously.
- Hands-on inquiry-based instruction increases comprehensibility by creating a common experience for all students.
- Placing vocabulary in context helps with new vocabulary.
- Working in small groups’ increases interaction through exploring together and sharing observations.
- Watching a short film will increase comprehensibility by providing a visual of a local scientist’s research.
- Questions about soil will activate prior knowledge.
• Watch Dr. Kyle Palmquist’s video
  o Ask students if they have any questions about what was said in the video, including any vocabulary words not understood.
  o Explain that learning about the properties soil and how different soil types can determine the type of vegetation that can grow in a particular landscape.
  o Explain that they will be learning more about soil through various activities and investigations.
  o Inform students that research scientists do this type of investigation to better understand the soil they are working in and it provides them with information about the type of vegetation expected to be found in this landscape.

**Explore:**
Approximately 20-30 min each activity

Physical properties could be explored one day and chemical properties another

Students will be introducing to a variety of scientific methods to study soil. They will look at both the physical and chemical properties

**Soil Particle Size Demonstration:**
• Students will be introduced to the three particle sizes that can be found in soil, (Sand, silt, and clay).
• Divide students into small groups and give each group a small sample of sand, silt, and clay.
• Have students make observations about sizes of the three soil particle types.
• Students will write and draw their observations to create a model of soil particle sizes in their naturalist journals. (F1)
• Pose the following: “Using what you know already and your observations, hypothesize which soil type would be better for holding water and which one would allow water to pass through quickly.”
  o Potential student responses:
    - The sand will let water through the fastest.
    - The sand will hold the most water because there is a lot of sand in the ocean.
    - The silt and clay will get muddy which means they are holding more water.
• In their small groups, students will be given two plastic bottles filled with water.
  o Students will add sand to one water bottle and time (using a stopwatch or having one partner count) how long it takes for the sand particles to sink to the bottom.
  o Then they will add the silt and clay to the second water bottle and time how long it takes these particles to sink to the bottom.
  o Students will record this data in their naturalist journals.
• Based on their results, students need to draw a conclusion about which

**Hands-on explorations increase both interaction and comprehensibility by creating a common experience for all students and provide context for new concepts and vocabulary.**

**These hands-on, inquiry-based explorations will also help to link prior knowledge to new learning about soil through practicing and engaging in a variety of scientific methods.**

**Drawing conclusions, explaining, and comparing will help increase higher order thinking through**
soil particle size would be best for holding or retaining water and which one would allow water to pass through quickly.

- Students need to record this in naturalist journals through words or drawings and mention if these results support their hypothesis.

- Have each small group share their findings with another group.

- If there were different results between the two groups, ask students to discuss why they think this might have occurred.

**Soil Layers Test:**

- Explain that another way scientists understand soil is by taking a soil profile. The researcher collects information about the compositions and properties of the soil as they dig down. *(Refer to The teacher background above for information on the different horizons that exist)*

- Have students go outside to practice taking a soil layer sample.

- Students will work together with soil cores to take a sample of the soil layers to see which horizons exist outside of their school.

- Instructor will demonstrate how to properly and safely use the soil core and will point out the horizons or layers that are present in this sample.

- Ask students what differences or similarities they notice throughout the soil sample.

- Using the soil horizon handout *(provided at the end of this lesson)* students will determine which layers are present in this sample. Emphasize the importance of O Horizon.

- Pose the following question, encouraging students to study the horizon diagram: “Why is the O horizon important for plants?”

- **Potential student’s responses:**
  - The organic matter in this layer provides nutrients plants need.
  - Plants roots can’t reach lower layers.
  - The bedrock layer is solid and would not let roots pass.

- Students will take a soil sample using the soil core.

- Students will be asked to share their findings with another group and compare and contrast the layers or horizons they notice.

- Groups will discuss what grows in the soil and indicate what plants are growing. Ask students to think about the following:
- Are there trees growing?
- Are there many different types of plants or only one type?

- Ideally, students should perform this scientific test in several locations so students can compare and contrast the different samples. It would work well to take a few samples at the school and then take a few samples on the sagebrush field trip. The instructor can also bring in a sample from a different location.

- Before moving on to the next activity, ask Students, “How does this test help us, as research scientists, to better explain this landscape?”
  - **Potential student responses:**
    - The amount of organic material will help explain what types of plant would be able to grow in this landscape.

*If the soil layer is shallow, trees will have a hard time growing because their roots cannot penetrate the bedrock layers.*

**Soil Ribbon Test:**

- The next scientific test will give the students the opportunity to apply what they have learned about soil particle size, water retention, and soil layers.

- Outside, students will be asked to perform a soil ribbon test. This is a test done by scientists to get a better idea of the composition of the soil to determine how much water it can hold. *(This can be done with any soil outside the school as well as on a field trip to the sagebrush)*

- Each student will have asked to collect a soil sample about the size of a ping pong ball.
  - Using magnifying glasses, they can take a closer look at the soil and share these observations with an elbow buddy.
    - Ask students to explain what the soil looks like, smells like, and feels like.
    - Ask students:
      - “Can you see any individual particles or grains?”
      - “What color is the soil?”
      - “What differences and/or similarities can you detect in this sample versus the sample you took with soil core?”
  - Students will add a small amount of water to their soil sample to test whether or not the soil particles stick together.
    - If they do stick together they should be able to form a ribbon-like form using their pointer finger, middle finger, and thumb.
o Pose the following: “What does this test indicate about the composition or particle size of your soil sample?”

- Potential student responses:
  - I was not able to create a ribbon-like form, which means there must be a lot of sand in this sample.
  - I easily could make a ribbon which means there must be more silt and clay particles which can stick together better than sand.

o Pose the following: “Using the results from this test what would you hypothesize about the water retention and water availability in this soil? What type of changes might you see with the changes of seasons”?

- Potential student responses:
  - If we cannot make a ribbon-like form with the soil there might be more sand in the soil, which might not hold water very well.
  - In the wetter seasons, winter and spring, there will be more water in the soil. If there is only silt and clay present, the water may pool and not trickle down to reach plant’s roots.

Have students discuss answers to these questions with an elbow buddy and then share out in smaller groups. (F2)

Soil Chemistry (pH test): (Can be done inside or outside)
- Explain to students that the next test will be about the chemistry of the soil. A test that scientists will often perform is a pH test. (See above for information about pH and how it affects soil)
  o The pH of the soil helps us to determine the acidity of soil, which can then determine which types of plants can grow in that particular soil.
  o To explain what an acid is, bring in vinegar or pickle juice as an example.

- Have students work in pairs to test the pH of the soil samples they have collected
  o Instructor may bring in a couple soil samples that are not from around the school for students to compare and contrast.

- Using the pH kits students will mix a sample of each soil sample with water and then using the provided test strips they will record the pH of each soil sample. (instructions are available in the kits)
  o Students can record their results in their naturalist journals by
labeling their soil sample (Soil Sample 1: outside school) and write or draw the results that appear on the test strip.

- On the board draw out a table for students to record their pH data they have collected. This will give the entire class the opportunity to visually see the results.
  - Pose the following question: “What similarities or differences do you see between the samples?” “Why do you think these exist?”
  - Potential student responses:
    - The samples from our school have a lower pH than the samples brought in from the other location, which means the soil near our school is more acidic.

<table>
<thead>
<tr>
<th>Elaborate: Approximately 15min</th>
<th>I used to think …but now I know:</th>
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<tbody>
<tr>
<td></td>
<td>Students will be asked to compare their ideas about soil at the beginning of this lesson to what they have learned.</td>
</tr>
<tr>
<td></td>
<td>Students will make a recording sheet (<em>example given below</em>) that consists of two columns. They can discuss ideas with a partner before recording their ideas individually.</td>
</tr>
<tr>
<td></td>
<td>Responses can be a combination of drawings, bulleted ideas, and complete sentences.</td>
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<td></td>
<td>Ask a few students to share their responses. (F3)</td>
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<tr>
<th>Evaluations and Assessment Check ins:</th>
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<tbody>
<tr>
<td>(D1): A quick review of what students know about abiotic factors.</td>
</tr>
<tr>
<td>(D2): These questions will help access student’s prior knowledge about soil to see what they know about how different soils support different vegetation which then supports different wildlife. It is getting at their knowledge and identification of those interdependent relationships that exist in an ecosystem.</td>
</tr>
<tr>
<td>(F1): Students will be asked to create a model in their journals that</td>
</tr>
<tr>
<td>(F3): Comparing results will increase higher order thinking through analysis.</td>
</tr>
<tr>
<td>(D2): Discussion with a partner will increase interaction and higher order thinking through comprehension.</td>
</tr>
<tr>
<td>(F1): Responses can be drawings, words, bulleted ideas, and complete sentences based on level of ELLs.</td>
</tr>
<tr>
<td>(F1): This activity will link prior knowledge with new learning.</td>
</tr>
<tr>
<td>(D1): Assessments will activate prior knowledge, increase interaction through</td>
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demonstrate the three different particle size that exist in the soil and their importance in water retention and water leaching. 

(\textbf{F2}): Through this scientific test student are able to apply what they learned in previous activities in order to determine the composition of the soil sample they are testing and predict its water retention capability. 

(\textbf{F3}): A self-assessment and reflection exercise that helps students recognize if and how their thinking has changed throughout this lesson.

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<tr>
<th>References:</th>
<th>Dr. Kyle Palmquist’s video</th>
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Chapter 5

Discussion

Overview

The purpose of this research was to develop a 5th grade science unit on the Wyoming sagebrush ecosystem that was aligned to the NGSS, incorporated the seven place-based principles, and was modified for English language learners through the inclusion of four ELL principles and their strategies and best practices. Nine 75-90 minute lessons were created for this unit. This chapter discusses the considerations that influenced the development of the unit including the research questions, factors that informed the development of the unit, research implications and connections, research recommendations, and a conclusion.

Research Questions

This research project aimed to answer the following questions:

How can the research literatures on place-based education principles, ELL strategies and best practices, and NGSS guide the development of a 5th grade science unit about the sagebrush ecosystem?

How can this unit:

1. Guide the connection of students to a local ecosystem through local scientists?
2. Align with appropriate 5th grade Next Generation Science Standards focused around ecology and ecosystems?
3. Include appropriate ELL strategies and best practices in order to make this science unit available for all students in a given classroom?

Findings to these research questions are addressed in the subsequent sections.
Factors that Informed the Development of the Unit, *A Sagebrush Expedition*

Multiple perspectives provided the insight for the framework used to develop this science unit. To do this, information was gathered from several sources to include the perspectives of the NGSS, PBE, ELL methods, and UW scientists conducting research in the sagebrush ecosystem.

**Backwards Design.** Backwards design played a key role in developing this unit. It served as a guide for setting up the structure of how the unit would look, the goals and objectives the unit was aiming to accomplish, and what needed to be included. In curriculum development, it is important to put emphasis first on the specific learning sought for students and the evidence required of this learning, before thinking about what activities and experiences need to be provided (Wiggins & McTighe, 2005). Using backwards design helped to guide this study in thinking about the overall goals for students, rather than focusing first on picking fun activities. Setting up the curriculum development this way leads each lesson to be a piece of the overall puzzle. The goal of each lesson was to provide students with information and tools in order to answer the overall essential questions. If an activity or experience did not accomplish this task it was removed from the overall unit or modified in a way that it could accomplish this goal.

**5E Learning Cycle and Assessment.** The 5E learning cycle was the structure for the suggested procedures within each lesson plan. This structure allowed activities and experiences to be divided into (a) how to *engage* students, (b) ways of *exploration*, (c) time for *explanation*, and (d) the opportunity to *elaborate* on what they learned. This structure encouraged the use of evaluation or assessment check-ins throughout the entire lesson plan instead of only at the end. Page Kelley’s (2008) work on assessment for science curriculum led to the incorporation of diagnostic, formative, and summative assessments. The variability of these assessment check-ins gives teachers the flexibility to evaluate their students using multiple methods. The variability
also provides scaffolding that lends well to the diversity that is often found within a classroom, and gives teachers more ways to understand what their students know and what they are able to accomplish.

**Next Generation Science Standards.** The NGSS (NGSS Lead States, 2013) guided the selection of standards incorporated into this science unit. The goal of the unit was to have it based on the Wyoming’s sagebrush ecosystem. Thus, life sciences and earth and space sciences standards were chosen. The NGSS also helped with deciding which grade level best fit with the unit. As Ecosystems are specified in 3rd and 5th grades, they were the natural choice. Fifth grade was chosen for this study because there was a 5th grade teacher who was willing to pilot the unit during the same year it was developed. Feedback from this classroom was invaluable in the development. Within each standard the three dimensions of NGSS are laid out in the performance expectations and they help guide teachers in choosing appropriate strategies. These three dimensions helped to direct the number of lesson plans in the unit and the objectives of each lesson plan.

**Place-Based Education.** One of the main goals for the Biodiversity Institute was to involve research scientists from the University of Wyoming who were conducting research within the sagebrush ecosystem. This allowed PBE to fall naturally into the framework of this unit because aligning curriculum with local partners and experts is one of the principles of PBE. The sagebrush ecosystem is the dominant landscape in Wyoming and therefore became a natural backdrop that could be used in many of Wyoming’s elementary schools. It is also readily available for students to explore and have hands-on experiences.

**English Language Learners.** The SIOP model is a common framework used for modifying and scaffolding curriculum for ELLs. For this study four ELL principles were chosen.
based on their overarching meaning. They were chosen through personal conversation with Dr. Jenna Shim, a professor at the University of Wyoming in spring 2016. By incorporating these four principles and the strategies and practices recommended to implement them, the majority of the SIOP principles were also incorporated into the unit developed for this study. These principles led to the inclusion of a language objective explicitly tied to the content objectives of each lesson plan. A building background section in each lesson plan explicitly provides examples of how teachers can access students’ prior knowledge, link prior experiences to new learning, and introduce new and key vocabulary. These principles also encouraged the addition of strategies and best practices that increased students’ comprehensibility, interaction, and higher order thinking. These principles directed the development of this science unit in a manner that would help give all students equal access to science education and science literacy (Warren, 2008).

**Research Connections and Implications**

**Connections.** Throughout the literature several connections among these three components were revealed. These connections help to explain the compatibility of these three frameworks, as well as how integrating PBE and ELL can help to strengthen NGSS curriculum.

**NGSS and PBE.** Research findings have indicated that there are several characteristics of compatibility that emerge between NGSS and PBE. This research was based on teachers’ experiences in integrating PBE into NGSS curriculum. The three characteristics that emerged were: (a) NGSS encourages teaching interdisciplinary curriculum which is one of the seven principles of PBE, (b) both NGSS and PBE emphasize the need for authentic forms of assessment, and (c) both NGSS and PBE allowed for creativity in curriculum development (Hackworth, 2015). NGSS encourages teachers to develop more interdisciplinary curriculum.
with the integration of the three dimensions of NGSS in order to encourage the connections among science content areas and other subject areas. One of the seven principles of PBE is ‘making learning interdisciplinary’. By integrating PBE with the NGSS teachers can create a perfect opportunity to make ‘learning relevant for students’, which is another of the seven principles of PBE (Hackworth, 2015).

Both NGSS and PBE emphasize the need for authentic assessment. Greenwood (2003) states, “Contemporary school reform takes little notice of place” (p.620) and diverts attention from meaningful and engaging educational approaches. Critics of standards-based reform often argue that accountability of high-stakes assessments leads instructors to adopt teaching strategies such as direct instruction. This leads to the abandonment of PBE such as inquiry and experiential, student-centered projects (Jennings et al., 2005). When diagnostic, formative, and summative assessments are embedded throughout lesson plans there is the opportunity for constant feedback for both students and teachers (Bybee, 2013). It also allows instructors to develop authentic assessments that are relevant to students’ lives using the NGSS (Hackworth, 2015).

The third area of compatibility between these two frameworks is that they both allow for creativity in the development of curriculum. The NGSS provides a framework of what instructors should be teaching without explicitly telling them how to teach these concepts. This allows instructors to feel a sense of ownership over their curriculum and increases the potential for them to include increased engagement and flexibility within their curriculum to meet the individual needs of their students (Hackworth, 2015).
Other connections between NGSS and PBE include engaging students in investigations that are inquiry-based, experiential, and project-based in order to promote problem-solving and critical thinking skills (Smith, 2007).

**NGSS and ELL.** The Framework and NGSS stress that as students participate in inquiry they must be engaged in the practices of science in order for understanding to occur. This includes active discourse around a scientific model or phenomenon. In order to teach science effectively using inquiry-based practices, elementary science teachers need to have definite content and process objectives in mind (Weinburgh et al., 2014). The NGSS (NGSS Lead States, 2013) accomplishes this by combining content and practice into a single objective. This single objective is then connected to other disciplines through the cross cutting concepts dimension of NGSS (NGSS Lead States, 2013). When students are engaged in exploratory investigations, with a purpose of finding answers to scientific questions, they do not need to be told the specific content objective in advance. When using the 5E model proposed by Bybee (1997), this occurs in the *Explore* phase. By providing a shared, hands-on experience, teachers can give students the context they need for asking more questions, analyzing data collected, and learning new scientific vocabulary. This context of scientific inquiry provides a rich environment where content and language can develop (Weinburgh et al., 2014). Thus, NGSS can encourage the successful use and development of scientific language and language for ELLs in the classroom.

**PBE and ELL.** Learning a new language is contingent on collaboration and support (Walqui, 2006). Aida Walqui (2006) states, “creating contexts for linguistic and academic learning occurs through the scaffolding of social interaction” (p. 163). Scaffolding is a strategy that aims to provide support and structure upfront and then decrease the support as students build confidence and become more independent. Therefore, scaffolding can be used when teaching
ELLs. Content learning can be achieved at a faster rate when collaboration and assistance by peers occurs with ELLs. This is evidence of the inclusion of social interaction. These students can achieve more with others than they might be able to achieve alone (Walqui, 2006).

Use of collaboration is directly linked with the PBE principle, ‘engaging students in experiential and project based learning’ because when ELLs work hands-on with their peers they are able to learn more than if they were trying to accomplish something alone. Collaboration can also be seen through the use of PBE principle, ‘engaging students in investigation, inquiry, and problem solving.’

Another connection between PBE and ELL is the contextual factors in second language acquisition. Individual, social, and societal contextual factors affect student’s second language acquisition. ELLs’ native language, their background, the attitudes towards the learner’s culture, and how they learn as an individual are all factors in learning a new language (Walqui, 2000). If language is taught with little to no context, students will have a much more difficult time being able to grasp this new language. Principles of PBE that address context include: (a) fostering love of one’s place, (b) focusing on local issues and using local experts, (c) learning takes place in the school yard, local community, and local environment, and (d) learning is personally relevant to students. When concepts are taught within the context of a student’s local community, culture, and environment students are able to gain a deeper understanding of what is being taught because the learning has become relevant and thus more meaningful to them (Smith and Sobel, 2010). This is equally true for ELLs (Walqui, 2000).

**NGSS, PBE, and ELL.** There are many connections among these three frameworks, which makes their application to curriculum an easier task. There were several themes that emerged through the literature connecting NGSS, PBE, and ELL. These emerging themes
include the following: (a) Use of inquiry-based, hands-on experiential learning, (b) Importance of building background and contextualizing what students are learning, (c) Interdisciplinary curriculum, (d) Authentic assessment, and (e) Creativity in curriculum development.

The three frameworks discuss the importance of inquiry-based, hands-on experiential learning. The NGSS incorporate this idea through the scientific and engineering practices dimension that engage students in scientific inquiry. In this case inquiry is specifically tied to the practice of doing science in a way that mirrors what scientists do. PBE discusses the importance of inquiry-based instruction in creating a more meaningful learning environment, and English language learning demonstrates how this learning can increase interaction among peers.

Building background in regards to accessing student’s prior knowledge, linking prior experiences to new learning experiences, and focusing on key vocabulary is one of the four main principles of ELL. However, building background also fit the goals of NGSS and PBE through creating a progression of knowledge that is connected to the students’ world through PBE principles.

The application of all three frameworks can lead to the creation of interdisciplinary curriculum through the inclusion of the NGSS’s crosscutting concepts, PBE principle of making lesson plans that are interdisciplinary, and inclusion of language objectives that are explicitly linked to concept objectives for ELLs.

The use and scaffolding of authentic assessment also play a key role in these three frameworks. NGSS demonstrates this through the scientific and engineering practices dimension. Lenski et al. (2006) states that instructors are able to develop authentic assessments that are relevant to their students’ lives using the NGSS. When teachers adopt a multidimensional
approach that includes both authentic and alternative assessments, they are able to successfully evaluate their ELLs’ progress in a more appropriate and fair manner.

Lastly, the literature demonstrates how the use of these three frameworks allows for creativity in curriculum development. The NGSS provides teachers with the scientific concepts, practices, and big ideas they should be teaching their students. However, it does not tell them how to teach these concepts. This allows for space and flexibility to include PBE principles. For example, a 5th grade science teacher may want to teach about interdependent relationships in an ecosystem. Instead of teaching this concept using a distant ecosystem such as the African Sahara Desert, Wyoming teachers could use the sagebrush ecosystem. They would be able to reach the same standards using their local environment. This contextualizes the concepts and can create more meaning and deeper understanding for students. ELLs are able to experience this concept even if they lack the language to adequately describe it. Figure 8 below demonstrates these connections among all three frameworks.
Figure 8. Connections among the three frameworks: NGSS, PBE, and ELLs. The connections include: inquiry-based, hands-on experiential learning; building background and contextualizing learning; interdisciplinary curriculum; authentic assessment; and creativity in curriculum development.

Implications

As noted in the statement of the problem, as the number of ELLs in the classroom continues to increase, it is crucial that teachers begin adjusting and scaffolding their lesson plans and curriculum to meet the needs of these students. By modifying lesson plans for ELLs, teachers can provide the same high-quality, academically challenging, and meaningful learning to all students in their classroom. The inclusion of PBE principles in the development of curriculum units using the NGSS can support and increase understanding of these science standards through relevant and meaningful application. The literature provided support for how a science unit aligned with NGSS, including PBE principles, could be modified and adjusted to meet the language needs of ELLs without sacrificing content.
Science teachers are needing to align their science curriculum and lesson plans to the NGSS and using PBE principles is one way to provide meaning and context to the topics and themes they are teaching. This meaning and context is transferred to creating a learning environment better suited for ELLs as they are able to relate to what is being taught, which lends to a deeper understanding of content.

**Research Questions**

The themes found in the literature were a crucial part of the development of this science unit. The three dimensions of NGSS that are specific to teaching 5th graders about ecosystems, the seven principles of PBE and the use of local community members, and four ELL principles guided the modifications, adaptations, and scaffolding that was used in the development of this science unit. The research literature supported the inclusion of these three frameworks within one curricular unit in order to provide context, make learning more meaningful and create a learning environment where all students have the same opportunity to engage and learn.

Including local UW research scientists in the study gave students the opportunity to connect with the scientists and the research they were doing. By adjusting the scientists’ research in a manner that made it more accessible to 5th graders, students had the chance to learn about current sagebrush ecosystem research. On field trips students were accompanied by these scientists, which helped create a deeper connection between students and their local ecosystem by learning through hands-on, inquiry-based experiences out in the actual sagebrush.

The unit was aligned with appropriate 5th grade NGSS focused around ecology and ecosystems through the use of the NGSS Lead States (2013). These guided the content objectives of each lesson plan. The content objectives then guided the language objectives. Appropriate ELL strategies and practices were included through the guidance of four ELL principles. The
literature supported that the use of these strategies and practices can create a curricular unit that can make science and science practices available to all students in a given classroom.

**Limitations**

There were several limiting factors in this research study. One limitation in this study was time. Lack of time led to the piloting of the unit prior to its final version. Modifications and adaptations for ELLs were made but were not explicitly highlighted throughout the unit. The videos of the research scientists took longer to create than expected, which led to only a couple of them being able to be included in the unit.

Another limiting factor was the partnerships included in the development of the unit. Three of the research scientists were able to participate in the pilot of the unit. Although this was a valuable addition to the unit, their participation is not sustainable. This was the purpose of developing videos. In this way students can learn about research being conducted locally even if the scientists cannot be physically present.

A third limitation was the facts that it is unclear whether or not the strategies and modifications put in place were effective. Further research should measure whether these strategies and modification are effective and can lead to a higher success rate of elementary ELLs in understanding scientific concepts. A fourth limitation could occur in the future when the unit is taught by teachers who are unfamiliar and untrained within NGSS, PBE, and ELL. If teachers do not have experience working with these three frameworks the implementation of this unit could be a daunting task. Therefore, professional development within these three areas could be vital for the unit to be successful.
Future Research and Recommendations

As suggested by the literature review this research may be the first of its kind in terms of developing a science unit that incorporates NGSS, PBE, and ELL. The results in the recommendation section are intended to guide further research and development in this area.

Curriculum as a “living document”. By regarding this 5th grade science unit as a living document, it can continuously be updated in order to meet the needs and goals of the Biodiversity Institute, 5th grade teachers, and ELLs in the years to come. This can be accomplished through seeking feedback from teachers who implement the unit in their classrooms.

Unit evaluation. The unit was piloted in a 5th grade classroom in Baggs, Wyoming. The feedback provided by both the teacher and the students led to revisions and modifications to the lesson plans. Several iterations of lesson plans were done before a final copy was produced. In the future it would be valuable to evaluate the effectiveness of the unit on helping ELLs understand and grasp the science concepts being taught. Now that the unit is developed, it could be implemented again with methods put in place to assess pre and post knowledge from students and include interviews of students and teachers on the effectiveness of the strategies used. If we know these strategies benefit ELLs, would there be a value added that these strategies would also increase the learning outcomes for all students.

Professional development in NGSS, PBE, and ELL. A challenge of developing curriculum using NGSS, PBE, and ELL is the lack of knowledge and understanding of what they are and how to effectively incorporate them into curriculum. Many teachers have not been trained in NGSS, PBE, or ELL and this creates an implementation problem. Professional development for science educators that includes how to use the three dimensions of NGSS, what
PBE is and how to use the principles in the classroom, and how to modify lessons for ELLs would greatly benefit teachers.

**Key strategies and practices to include in science curriculum development.** Based on this study, there are key strategies and practices that should be included in any science unit in order to increase understanding and create more meaningful learning. These include: (a) the use of inquiry-based, hands-on experiential learning, (b) the importance of building background and contextualizing what students are learning, (c) making curriculum interdisciplinary, (d) creating authentic assessment, and (e) incorporating creativity in curriculum development. This leads to a science unit that is meaningful, place-based, and creates equal opportunities for learning to occur among all students within a given classroom.

**Conclusion**

This curricular framework has the potential to make positive changes in 5th grade science classrooms that include ELLs through providing context to what they are learning. This context can then create connections that lead students towards more meaningful learning through deeper connection with their local community and environment. The NGSS provides *what* teachers or developers should include in their curricular units, and the PBE and English Language Learning frameworks provide *how* they can teach these science units. The combination of these three frameworks help to create an equal-opportunity, learning environment for all students so they can continue to work towards being scientifically literate. The literature helps demonstrate that these three frameworks do not need to be viewed separately or in opposition. Rather, the literature reveals that the principles of PBE and ELLs can serve as guides for developing new curriculum that aligns with the NGSS.
References


Ortmeier-Hooper, C. (2008). English may be my second language, but I'm not ESL'. *College Composition and Communication*, 389-419.


