Supplemental Curricula and Science and Engineering Practices in the Next Generation Science Standards: Developing a Tool for Identification and Alignment

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Supplemental Curricula and Science and Engineering Practices in the Next Generation Science Standards: Developing a Tool for Identification and Alignment

By

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B.A., University of North Texas, 2008

Plan B Project

Submitted in partial fulfillment of the requirements for the degree of Masters in Science in Natural Science/Mathematics in the Science and Mathematics Teaching Center of the University of Wyoming, 2014

Laramie, Wyoming

Masters Committee:

Dr. Ana Houseal, Chair
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Bob Fuhrmann, National Park Service
Abstract

It has been nearly twenty years since the last national science standards, the American Association for the Advancement of Science’s (AAAS) *Benchmarks for Science Literacy (Benchmarks)* (AAAS, 1993) and the National Resource Council’s *National Science Education Standards (NSES)* (NRC, 1996) were published. In 2013, the Next Generation Science Standards (NGSS), developed using the latest research in science and science teaching, were released. Unlike previous standards, the NGSS are divided into three dimensions, (a) disciplinary core ideas (DCIs), which is the content, (b) crosscutting concepts (CCCs), which are the connections between science subjects, and (c) scientific and engineering practices (SEPs), the processes used in doing science. In the year since their publication, educators are still learning about the standards and how to best implement them in the classroom. Their implementation could be manifested as adapting existing curriculum, developing new curriculum entirely, or adopting newly-released packaged curriculum. Due to the NGSS’s recent release packaged curricula will not be available for some time. This project developed a rubric to help educators identify SEPs in existing supplemental curricula. This rubric was tested using the Expedition: Yellowstone! (EY) supplemental curriculum
To Trey
Acknowledgments

There are many people who have helped me as I have worked on this project and I am grateful for the opportunity to thank a number of them here. I would like to thank Dr. Ana Houseal, my committee chair, for her constant guidance and support in the completion of this paper. From her I learned a tremendous amount not only about science education, but also about life. I am incredibly appreciative of her advice and encouragement during this process. I would also like to thank my committee members, Dr. Brian Barber, Dr. Diana Wiig, and Bob Fuhrmann, YNP Youth Program Coordinator, for their willingness to assist this undertaking. I am very grateful for their flexibility and patience during this process. Additionally, without the Science and Mathematics Teaching Center’s logistical and financial assistance it would not have been possible for me to attend the University of Wyoming.

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Chapter 1

Introduction

Background

Environmental education (EE) seeks to provide students with knowledge about the natural world and how they impact it, and at the same time help them develop motivation and skills that allow them to maintain or restore the environment (Ballantyne, Packer, & Everett, 2005; Ballantyne & Packer, 2002). An important area of EE is residential environmental education (REE). Each year many students participate in REE programs as a part of their formal education. Typically, students come as a class or school, spend at least one night at the facility, and participate in EE programming (Dettmann-Easler & Pease, 1999).

The National Park Service is one provider of such programs. Some National Park Service units offer teachers and students the opportunity to stay and learn in the national park setting while following a curriculum aligned to regional states’ standards (National Park Service (NPS), 2014). One particular program offered through Yellowstone National Park’s (YNP) education division is Expedition: Yellowstone! (EY). Each year fifty school groups, about 1500 students, attend EY. Students in grades four through eight participate in a variety of outdoor lessons and activities designed to increase environmental and cultural knowledge about the Greater Yellowstone Ecosystem, explore current issues affecting the area, and promote worldwide stewardship and preservation of ecosystems (National Park Service (NPS) & Yellowstone National Park (YNP), 2004). Participants spend four or five days in YNP and are instructed by park rangers.
EY provides a supplemental curriculum that includes lessons for teachers to use both before and after their EY REE experience. It covers the three-content areas of Geology, Ecology, and Human History. A fourth area that includes the National Park Idea is embedded within the three content areas. See Appendix C for a sample lesson from the ecology unit of the curriculum. This curriculum is currently aligned to Idaho, Montana, and Wyoming state standards (NPS, 2014). It was chosen for this project due to its focus on inquiry and the need for the curriculum to be re-aligned to the new standards by Yellowstone National Park.

**Statement of Problem**

Alignment of curriculum to current state and national standards is an important factor in determining ability of teachers to take their classes to non-formal learning environments. Gruenewald & Manteaw (2007) found that under the pressures of the No Child Left Behind Act (NCLB) of 2001, support for EE programs, especially those in non-formal settings, was only provided if the programs could be linked to enhanced student achievement or improved test scores. Anderson, Kisiel, & Storksdieck (2006) examined teachers’ perspectives regarding field trips in the U.S., Canada, and Germany and discovered similar curricular concerns. Teachers in the three countries deemed connection of the field trip content to school-based curriculum a necessity that helped them gain legitimacy for their trip (Anderson et al., 2006).

In April 2013, the Next Generation Science Standards (NGSS) were released. The NGSS represent what we currently believe it means to be proficient in science with the combination of three dimensions communicated within each standard: (a) scientific and engineering practices (SEP), (b) crosscutting concepts (CCC), and (c) disciplinary
core ideas (DCI) (NRC, 2012). A list of acronyms relevant to this project and their definitions are provided in Appendix D.

In order to remain relevant and continue to support program participation amidst the constraints described above, the EY curriculum and all other REE curricula, should be aligned to the NGSS. However, it is not enough to align content with the DCIs (content) alone. The SEPs (processes) and CCCs (connections) must be considered as well. Each curriculum needs to be evaluated by an educator who is well versed in the NGSS. It is important that this person is able to examine lessons for content as well as processes and the big ideas – the CCCs. This is an intensive process that many educators do not have the proper time or support to accomplish (Reitsma, Marshall, & Chart, 2012).

Purpose and Research Questions

Bybee (2013) compares the relationship of the following three components, (a) the science content in NGSS, (b) curriculum and instruction, and (c) science teachers’ knowledge and skill for teaching content, to a three-legged stool. In this analogy the goal is stability. When one leg changes the other two must change also. In this case, some science content and process skills have changed with the release of the NGSS. Now, curricula, instruction, and the knowledge and skills of science teachers must adjust.

The purpose of this study was to analyze the lessons in the EY curriculum and determine their alignment to the NGSS, with a specific focus on the SEPs. Methods for determining alignment between standards and assessments have been the focus of research since NCLB (Martone & Sireci, 2009); the curriculum is the necessary connection between standards and assessment.
New standards present new challenges. One year after the release of NGSS (NRC, 2013) educators, administrators, and others are still learning about the standards and determining the best way to implement them in the classroom. This implementation could manifest as adapting existing curriculum, developing new curriculum entirely, or adopting newly released packaged curriculum. Due to the newness of the NGSS, packaged curricula that fulfill the intent of the standards may not be available for some time, so initially the first two will be of primary focus. Regardless of the chosen option, the first step will most likely be a determination of what DCIs, SEPs, and CCCs are already present in current curricula.

This project aims to aid in identifying Science and Engineering Practices in current supplemental curriculum and by providing a newly developed tool for educators to judge SEP alignment to supplemental curricular pieces.

The primary question addressed in this study is:

How can scientific and engineering practices be identified within existing supplemental EE curricula?

Secondary questions will examine:

1) How can current research on science education be used to develop a tool that determines alignment of written curriculum to the NGSS, specifically to the scientific and engineering practices?

2) What science and engineering practices are represented in the EY curriculum?

3) Can others use this tool to achieve similar results as the author?
Chapter 2

Literature Review

In 2009, President Barack Obama addressed the National Academy of Science at their annual meeting saying, “Today, of course, we face more complex challenges than we have ever faced before… Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before” (Office of the White House Press Secretary, 2009). We live in a global society and face challenges unlike any others in our past. Our main source of energy, fossil fuels, are being slowly depleting and their use is contributing to global climate change. World population has surpassed seven billion, forcing us to need more living spaces, food, clean water, and to use more energy than ever before (United States Department of Commerce, 2014). Science and engineering will play critical roles in innovating and overcoming those challenges.

Currently in the United States, there are too few people with strong science backgrounds and many that lack basic science knowledge (NRC, 2012). The science, technology, engineering, and mathematics (STEM) workforce accounts for more than 50% of the United States’ sustained economic growth but employs only five percent of the total U.S. workforce (Jobs for the Future, 2007). The National Science Foundation reports that the “majority of the general public knows a little but not a lot about science” and that less than one-fifth of Americans meet a minimal standard of civic scientific literacy (NSF, 2004, p. 15). In this report science literacy is defined as “knowing basic facts and concepts about science and having an understanding of how science works” (NSF, 2004, p. 15).
There is widespread agreement that changes in K-12 science education may be an initial step in reversing this trend. The United States Department of Labor (2007) is researching how it can contribute to improving K-12 STEM education. The Education Commission of the States, in a report by Coble & Allen (2005), claimed that the key to keeping America competitive in the global economy is the ability of our education system to graduate students with strong STEM knowledge. The National Academy of Science (2008) recommended recruiting 10,000 science and mathematics teachers annually by offering undergraduate scholarships, increasing the science and engineering knowledge of current teachers. This would be accomplished through teacher professional development opportunities, and in this way would increase the number of high school students who take and pass Advanced Placement (AP) or International Baccalaureate (IB) courses and tests. President Obama has called for the recruitment and training of 100,000 new effective STEM teachers by 2021 and an increased focus on exposing females and minority groups to STEM courses (“Educate to innovate”, n.d.)

If students are to be successful in science they first need to have an interest in it. The use of supplemental science curricula has the potential to engage students and help prepare them to be a scientifically literate adult (NRC, 2009). REE programs that offer supplemental curricula can introduce new concepts and provide direct experiences with phenomena not accessible in a classroom (NRC, 2009). These experiences can lead to greater gains in environmental knowledge than a classroom experience (Knapp & Benton, 2006). In addition, experiences in informal settings are remembered into adulthood. Falk & Dierking (1997) found that of 123 adult subjects, 96% could recall
details from at least one school field trip and most often that field trip was to a nature center or natural site.

For the purposes of this study, a supplemental curriculum was defined as a written curriculum used in addition to a formal school or classroom curriculum. Supplemental curricula enrich and expand, but do not replace, the formal curriculum. Some supplemental curricular lessons may be conducted in the classroom, but others take students out of the traditional formal learning environment and into an informal environment such as a national park or nature center.

Residential EE programs, such as EY in Yellowstone National Park, The Great Smoky Mountains Institute at Tremont in Great Smoky Mountains National Park, and school programs offered by the Delaware Nature Society are all examples of programs that use a supplemental curriculum as they teach students. These programs range in length from an hour to multi-day experiences and the curricula are often aligned to particular state science standards. These programs allow students to participate in direct experiences connected to content they have been learning about in the classroom.

Farmer, Knapp, & Benton (2007) interviewed students who attended a program in the Great Smoky Mountains National Park. A year after attending, students were still able to recall and describe ecological concepts (Farmer, Knapp, & Benton, 2007). Knapp and Benton (2006) found similar results in students after attending an EY program. They interviewed EY participants one year after their experience. The majority of students associated a positive emotion with the program and all students remembered content from the trip (Knapp & Benton, 2006). These research studies demonstrate that programs such
as these have lasting effects on students and may help lay the foundation for further science learning.

Why NGSS?

The NGSS are the first national science standards to be developed since 1996 (NRC, 2012; NRC, 2013). The remainder of this literature review will provide a context for understanding the NGSS, with a focus on the science and engineering practices (SEPs) and their importance to supplemental curricula.

Before the NGSS, science educators relied on the American Association for the Advancement of Science’s (AAAS) *Benchmarks for Science Literacy (Benchmarks)* (AAAS, 1993) and the National Resource Council’s *National Science Education Standards (NSES)* (NRC, 1996) for guidance at the national level. These documents represented the latest science education research at that time, but adoption of the standards was sporadic. States, and some individual districts, developed their own standards for science education based off the recommendations in these two documents (Roseman & Koppal, 2008; Schmidt, 2003).

It is impossible to rely on any research or set of standards indefinitely. In the more than twenty years since the publication of the *Benchmarks* (1993) and over fifteen since the *NSES* (1996) there have been many new scientific discoveries. For example, we used to believe that Mars could never support life. Now we know that the surface of Mars once had water (Bryn, 2010).

In addition, we have also improved our understanding of science learning and teaching (NRC, 2013; Bybee, 2013; NRC, 2000, 2007a, 2007b). For example, we know that science learning should reflect the interconnected nature of science as it is conducted
in the real world. Scientists use content knowledge and skills concurrently. The NGSS recognizes and emphasizes that skills should not be devoid of content and content not devoid of skill (NRC, 2013). This is evident in the performance expectations (PEs) outlined in the NGSS. PEs are the aspect of NGSS that most directly compare to standards as they were written in the NSES. Unlike standards that separate content and practice, NGSS’s PEs focus on a student’s ability to apply skill to content.

Second, science is not a set of isolated facts. The NGSS have been build as a progression of knowledge from kindergarten through twelfth grade. Each year builds on the previous ones so that by the end of twelfth grade a student has an overall understanding of science. There are a smaller number of core ideas in NGSS than were in the NSES allowing teachers to go more in depth than before. The focus is not on memorizing facts and details, but on understanding the “big ideas” of science.

Although states are not required to adopt the NGSS, since they reflect the most recent research and best practices in science education (NRC, 2013) the NGSS will undoubtedly become a driving force behind any state that chooses to write their own standards.

**A brief history of NGSS.** The NGSS were created in a two-step process through partnerships among the National Research Council (NRC), National Science Teachers Association (NSTA), American Association for the Advancement of Science (AAAS), and 26 lead state partners. The first step was the development and publication of the Framework for K-12 Science Education (hereafter referred to as The Framework) by a group of scientists, educational researchers, and educators. Published in 2012, the Framework contained the latest research on science learning and teaching and the science
all K-12 students should know (NRC, 2012). This document drew heavily from Taking Science to School (NRC, 2007b) and Ready, Set, Science! (NRC, 2007a) where a new definition of proficiency in science had been established. According to these documents, students who are proficient in science:

- know, use, and interpret scientific explanations of the natural world;
- generate and evaluate scientific evidence and explanations;
- understand the nature and development of scientific knowledge; and
- participate productively in scientific practices and discourse (NRC, 2007a).

These four statements are referred to as strands of proficiency and represent student learning goals. The four stands become the backbone for the Framework and eventually the NGSS.

In the second step, the standards were written so they reflected the ideas presented in the Framework (2012). Achieve, Inc. facilitated the writing process among 41 writers and 26 lead states partners. Achieve, Inc. is an independent, non-partisan, non-profit education reform organization that facilitates efforts between states, leaders, and organizations to promote college, career, and citizenship readiness (Achieve, Inc., 2014). The NGSS were reviewed by states numerous times and put up for periods of public comment twice. In April 2013, after countless revisions and improvements, the NGSS were released for states to consider for adoption. As of March 2014, eleven states and the District of Colombia have adopted the NGSS.

**NGSS Structure**

In the United States, K-12 science education has been criticized for not organizing concepts across multiple years, emphasizing an “inch high, mile wide” curriculum, and
lacking opportunities for students to “do” authentic science; that is science as it is actually done by scientists (Li, Klahr, & Siler, 2006; NRC, 2012; Schmidt, 2003). The NGSS seek to overcome those criticisms by shifting how science is taught, beginning with how the standards are organized.

Unlike the *NSES* and many state standards, the NGSS are separated into three dimensions, consisting of the disciplinary core ideas (DCIs), scientific and engineering practices (SEPs), and crosscutting concepts (CCCs). United, these dimensions form the performance expectations (PE). PEs are classified by subject (Physical Science, Earth and Space Science, Life Science, and Engineering Design) then further classified by grade level. For K-5 PEs are set for each grade and for 6-12 they are banded into middle and high school expectations. This accommodates the structure of courses at the secondary level (NRC, 2013).

A PE contains pieces of each dimension and may seem similar to what has traditionally been thought of as a standard. However, PEs vary significantly from traditional science standards because they bring content and practice together into one statement. Due to the complexity of PEs, caused by combining parts of each dimension, many lessons are needed to teach one standard. This is a change from previous standards where one lesson could contain multiple standards.

Additionally, the PE is the end goal, but only states the beginning of what may need to be addressed to achieve it. If an NGSS standard were an iceberg, the PE would be the tip above water. To truly understand what is being asked of students, educators must dive deeper and look below the surface. There they will find the SEPs, CCCs, and DCIs, the foundation of the PEs and the pieces crucial to NGSS implementation.
**Dimension 1: Scientific and engineering practices (SEPs).** Research has shown that students learn science best when they are actively engaging in the practices of science (NRC, 2007a). The SEPs were designed to give students the opportunity to actively “do” science in a scientific community. The practices are based on real-world activities of scientists and engineers and intended to give students a chance to explore and appreciate how experts do their jobs. The *Framework* (2012) and NGSS (2013) identify eight practices essential to a science and engineering curriculum. They are:

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 from evidence
8. Obtaining, evaluating, and communicating information (NRC, 2012; 2013)

The SEPs are similar to inquiry as defined in the *NSES* (Forbes, Biggers, & Zangori, 2013; NRC, 1996). However, the type of inquiry defined by *NSES* is just one form of scientific practice. A scientific practice “involves doing something and learning something in such a way that the doing and learning cannot really be separated” (NRC, 2007a, p.34). NGSS stresses this connection of content and process. SEPs do not replace inquiry, they enhance the teaching and learning of science (Bybee, 2011). Bybee (2011) goes on to explain that SEPs are not just skills or learning strategies they are simultaneously learning outcomes.
When SEPs are viewed as learning outcomes, students develop the abilities described in practices and understand how they are used to create scientific knowledge. They can also be interpreted as guidance for instructional strategies. When viewed this way, they become a method of reaching the learning outcomes just described, and outcomes associated with understanding DCIs or CCCs (Bybee, 2011).

**Dimension 2: Crosscutting concepts (CCCs).** CCCs are comparable to the unifying concepts and processes described in the NSES (NRC, 1996). They are themes and concepts that cross disciplines and grade levels connecting engineering, physical, life and earth/space sciences (Duschl, 2012). As with SEPs, CCCs should not be taught in isolation, they must be coupled with content. The Framework (2012) identifies seven CCCs that are found in multiple areas of science and engineering. They are:

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change (NRC, 2012).

The seven CCCs are central to understanding science and engineering. In the past students have been expected to grasp their meaning without much instructional support (NRC, 2012). Their use has been implied, not explicit. The Framework placed CCCs as the second dimension in hopes that they would be given more consideration when standards, curricula, instruction, and assessments are created. By giving these concepts...
common names and making them explicit, educators across grade levels and disciplines can help students develop a “cumulative, coherent, and usable understanding of science and engineering” (NRC, 2012).

**Dimension 3: Disciplinary core ideas (DCIs).** DCIs are the science and engineering content knowledge. In response to the typical breadth without depth model the authors of the *Framework* narrowed the amount of science content in the standards down to 13 core ideas, four in physical science, four in life science, three in earth and space science, and two in engineering, technology, and applications of science (NRC, 2012). A limited number of core ideas allow educators to go beyond teaching only knowledge and into teaching the processes of science. This choice was made,

In order to avoid the shallow coverage of a large number of topics and to allow more time for teachers and students to explore each idea in greater depth.

Reduction of the sheer sum of details to be mastered is intended to give time for students to engage in scientific investigations and argumentation and to achieve depth of understanding of the core ideas presented (NRC, 2012, p. 11).

Focusing solely on scientific facts, without understanding how those facts came to be, misrepresents science (NRC, 2012). Now, over the course of a K-12 career, students are expected to master the big ideas in science rather than simply memorize facts.

**K-12 progressions.** In the United States, since 2001, K-12 education has provided limited opportunities for science learning, especially at the elementary level. Elementary science instructional time has decreased, while time spent on language arts and mathematics has increased (Blank, 2013). In addition, the majority of science education consists of disconnected isolated units of instruction all given equal priority
(Duschl, Maeng, & Sezen, 2011). This is a poor design for effective knowledge building (NRC, 2007b). The *NSES (1996)* and the *Benchmarks (1993)* have been criticized for listing too many topics to be covered sufficiently in a year and not specifying which of these topics are most important (NRC, 2007b). This led to a lack of focus on how students’ knowledge can be enriched and increased from year to year and often resulted in repeated, shallow coverage of topics (NRC, 2007b).

Science learning happens over time. One of the best ways for students to learn scientific concepts is to experience them over multiple years, each year building on the ideas of the previous year. Science education should “function vertically across grades/years and horizontally within a given school year” (Duschl, Maeng, & Sezen, 2011, p.124).

These ideas led to the development of learning progressions. Learning progressions are a “pedagogical approach that emphasizes the learning of big ideas and practices in a domain over extended periods of time” (Shea & Duncan, 2013, p. 7). They describe paths that students take as they develop increasingly more complex ways of thinking about concepts (Shea & Duncan, 2013).

Learning progressions are built around key concepts in a given domain and foster conceptual understanding instead of memorization of isolated facts. They specify an upper anchor, which is what students should know and be able to do by the end of the progression, and a lower anchor, which are the knowledge and skills with which the students begin the progression (Shea & Duncan, 2013). Learning opportunities are extended because students are given opportunities to predict, understand, and explain phenomena, and to solve problems over time (NRC, 2007a). Students revisit concepts
throughout their K-12 science career, each time with increasing depth and this repeated exposures help build conceptual understanding of big ideas. With this in mind, the NGSS were written as a set of learning progressions, assuming that each year students have attained all of the content and skills of the previous year.

At the time of this project, one year after the release of the NGSS, teachers and students are in a lag period. In 2014, students in 3rd-5th grade did not have the assumed background knowledge and skills. If a kindergarten class in the 2014-15 school year began a NGSS aligned curriculum it would be at least three years (2017-18) until third graders arrived with the science background they needed. Because of this lag period it will take time before our education system has completely caught up to the high standards set forth in the NGSS (Stage, Asturias, Cheuk, Daro, & Hampton, 2013).

**Appendices.** The progressions in NGSS are presented as matrices in appendices E, F, and G. Figure 1 is an example of one such matrix. This appendix demonstrate what students should know and be able to do with regards to Developing and using models by the end of each of the specified grade bands (K-2, 3-5, 6-8, and 9-12). There is a set of progressions for each dimension (CCCs, SEPs, and DCIs). The separation of each of the dimensions in these progressions does not mean that each dimension should be looked at in isolation. The authors of the *Framework* encourage educators to examine the progressions in all dimensions before designing instruction (NRC, 2012).
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<th>Grades 3-5</th>
<th>Grades 6-8</th>
<th>Grades 9-12</th>
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<tr>
<td>Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.</td>
<td>Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.</td>
<td>Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.</td>
<td>Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.</td>
</tr>
<tr>
<td>• Distinguish between a model and the actual object, process, and/or events the model represents.</td>
<td>• Identify limitations of models.</td>
<td>• Evaluate limitations of a model for a proposed object or tool.</td>
<td>• Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria.</td>
</tr>
<tr>
<td>• Compare models to identify common features and differences.</td>
<td>• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.</td>
<td>• Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed.</td>
<td>• Design a test of a model to ascertain its reliability.</td>
</tr>
<tr>
<td>• Develop a simple model based on evidence to represent a proposed object or tool.</td>
<td>• Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution.</td>
<td>• Use and/or develop a model of simple systems with uncertain and less predictable factors.</td>
<td>• Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.</td>
</tr>
<tr>
<td>• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).</td>
<td>• Develop and/or use models to describe and/or predict phenomena.</td>
<td>• Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.</td>
<td>• Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.</td>
</tr>
<tr>
<td>• Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.</td>
<td>• Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.</td>
<td>• Develop a model to predict and/or describe phenomena.</td>
<td>• Develop a complex model that allows for manipulation and testing of a proposed process or system.</td>
</tr>
<tr>
<td>• Use a model to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.</td>
<td>• Use a model to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.</td>
<td>• Develop a model to describe unobservable mechanisms.</td>
<td>• Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.</td>
</tr>
</tbody>
</table>

Figure 1. Example of a SEP progression from NGSS Appendix F. SEP#2: Developing and Using Models K-12 progression (NRC, 2013).
Research on learning progressions still requires a tremendous amount of additional research (NRC, 2007b). There is more research on the progressions of core concepts than SEPs or CCCs (NRC, 2012). The progressions for SEPs and CCCs were created based on the judgment of the writers of the standards and Framework as there “very little research evidence on the developmental trajectory of each of these practice (NRC, 2012, p. 49). As the explicit use of SEPs and CCCs grows in classrooms across the United States, so will the body of research about them.

A Focus on SEPs

Both DCIs and CCCs will be relatively easy to identify in existing curriculum. DCIs can be matched to specific content within lessons. While there may be shifts in grade level or course content, the identification of core concepts should be fairly straightforward. CCCs are ideas that are inherently embedded into content. They will need to be identified in existing curriculum and made explicit.

The SEPs will be more difficult to identify because they vary significantly from inquiry as described in the NSES (1996). Since the release of the NSES, inquiry-based science has been the foundation for science education reform (Forbes, Biggers, & Zangori, 2013), but the SEPs more than just inquiry (NRC, 2012). The change from inquiry to practices is a critical part of NGSS explored below.

From inquiry to practices. While inquiry has been a focus of science education since the 1980s how it was used and defined by educators varied widely (Bybee, 2011). The NSES (1996) used the term inquiry to describe three different things: scientific inquiry, inquiry learning, and teaching inquiry (NRC, 1996). Educators frequently use terms interchangeably and without distinction (Anderson, 2002).
Asay & Orgill (2010) noted that even with the NSES inquiry definitions, teachers still seem unsure about the term. They found that teachers viewed inquiry as a process that is learned about and experienced, but not as a method for teaching specific content. Capps & Crawford (2013) found that even “highly motivated, well qualified teachers” could not accurately describe inquiry or demonstrate its use in the classroom (p. 521). The teachers’ descriptions of inquiry were more similar to descriptions of questioning strategies, student-centered teaching approaches, and hands-on teaching (p. 521). Morrison (2013) discovered similar results when she asked elementary teachers to define inquiry. Their definitions varied widely and were not always accurate (p.578).

The writers of the Framework agreed. When discussing the reasons for the use of practices in the NGSS, they recognized the ambiguity surrounding inquiry and how that has hindered science education in the past stating that it has lead to “widely divergent pedagogical objectives-an outcome that is counterproductive to the goal of common standards” (NRC, 2012, p. 44).

The SEPs could be in the same situation as inquiry twenty years after the release of the NGSS, where their meaning has been lost or misunderstood and even the best teachers are not involving their students in scientific practices (Capps & Crawford, 2013). This is an issue that can be avoided, but only with sustained professional development. The teaching of SEPs will require new instructional approaches and with any new instructional approach, if teachers are expected to use it they need effective, ongoing opportunities to learn about it, how to teach using the approach, and continued guidance and communication from professional development coordinators (Hanegan, Friden, & Nelson, 2009).
Informal Environments and Supplemental Curriculum

Society often treats learning, education, and school as synonyms. This contributes to the erroneous idea that schools alone are responsible for fulfilling the scientific knowledge needs of society (Falk, 2002; NRC, 2009). This is simply not accurate. Schools are not the only place to learn science. In actuality, most people get the knowledge, understanding, and information they need about science outside of a school setting (Falk, 2002).

Any learning that takes place outside of a formal school setting is considered an informal education experience (Brody, 2005). Informal education is also referred to as nonformal education or free-choice learning. Each year tens of millions of Americans learn about science by visiting museums, nature centers, zoos, state and national parks, by participating in school field trips, through activities like gardening, fishing, or hiking, and by using media to pursue their interests (NRC, 2009). Informal learning boosts the human nature of inquiry learning by providing an environment where people have access to phenomena and experiences that are normally difficult or impossible for learners to access (Heimlich, 1993; NRC, 2009).

Learning in Nature

Natural areas are informal environments often used for EE, REE, and school field trips. They can be places set aside for conservation such as parks or a wildlife refuge, which may include places distant from home and school environments, or they can be as close as the school grounds or a students’ backyard.

Learning in nature provides students with experiences unique from classroom learning. Brody (2005) noted that natural areas have distinctive advantages such as
fostering curiosity, engaging students through interaction with the natural environment, and improvement of student motivation and attitudes. James & Bixler (2008) found, in their interviews with children who attended a three-day REE program, that social interactions and sensory experiences played a prominent role in students’ sense making. In these environments, students learned the most from their peers. In addition, the unique sights and sounds of the coastal environment where the REE experience took place were recalled as the most meaningful. Dettman-Easler & Pease (1999) studied fifth and sixth grade groups at REE centers in the Midwest. Students who attended these programs reported greater gains in environmental literacy than students who received only classroom instruction.

**Memory.** Experiences outside of school are remembered and influence students’ lives over time. Stern, Powell, and Ardoin (2008) examined the influence of REE programs at Great Smoky Mountains National Park. After three months researchers found that students had maintained their knowledge and awareness of biodiversity and an increased commitment to environmental stewardship however, these students’ interest in learning and discovery and their connection with nature had faded.

**Supplemental Curricula**

Informal environments have the potential to improve science education by supporting classroom instruction (NRC, 2009). One way this can be done is through the use of supplemental curricula. Several REE centers focus their programming around a supplemental curriculum. Expedition: Yellowstone!, Tremont Institute at Great Smoky Mountains National Park, and the Delaware Nature Center offer a curriculum tailored to their location and specific state science standards.
Although a supplemental curriculum can be used to bridge informal environments and formal education, this is not easily accomplished. Differences in the organizational goals of schools and informal environments may hinder the blending of the two.

Typically informal environments include low consequence assessment and “safe, nonthreatening, open-ended spaces” for students to engage with science as opposed to high-stakes testing (NRC, 2009, p. 47). Informal environments also have their own mission statements and goals for science learning. For example, Expedition: Yellowstone! seeks to “teach the natural and cultural histories of Yellowstone National Park, to investigate current issues affecting the Greater Yellowstone Ecosystem, and to promote stewardship and preservation in the park and in home communities” (NPS & YNP, 2004). This could differ from a school or district mission, which may focus on preparing students for college or a career.

Formal education has objectives of its own. Educators must provide evidence of student progress and achievement throughout the year and schools must make adequate yearly progress (AYP) (Dee & Jacob, 2011). Since the implementation of the No Child Left Behind legislation, that evidence has been tied to the results of standardized tests, usually developed by the state (Dee & Jacob, 2011). The correlation between participation in a REE program and improved test scores is a difficult one to make, especially because most informal environments and REE centers do not have formal assessment procedures. The reasons for this may be due to program length (typically 3-5 days) and learning objectives that are challenging to measure (Ballantyne, Packer, & Everett, 2005). In addition to cognitive outcomes many REE programs have affective and behavioral learning outcomes that are impossible to measure using a state-wide
standardized test (Ballantyne, Packer, & Everett, 2005).

**School use.** In the United States, setting standards and taking tests has become a regular occurrence in K-12 education. If supplemental curricula are to be supported then they must also be correlated to standards (Gruenewald & Manteaw, 2007). When a supplemental curriculum for a REE program is aligned to state standards teachers and administrators can plainly see its value. Stern, Wright, & Powell (2012) looked at teacher motivation for participation in National Park Service curriculum-based programs. Both teachers and administrators cited connection to state required standards as a top concern for participation. If teachers could show administrators the relevance of the program to students’ academic achievement permission is typically granted (p. 44). Dettman-Easler (1999) recommended the linking of REE programs to classroom curriculum to improve the credibility of a REE program. They suggest that if a REE program can demonstrate improved learning, parents and administrators will be able to clearly understand its importance.

Teachers and administrators see the most value in supplemental curricula when they are aligned to standards. The number of states that have or will adopt the NGSS is growing. I believe eventually the NGSS or NGSS-based standards will replace current state standards in most states. It is important to begin aligning supplemental curricula to NGSS now to stay current with school district expectations.

**Rubrics**

Rubrics are a popular method of assessment evaluation in education due to their ease of use; they are concise, digestible, and easy to explain (Andrade, 2000; 2005). They can be constructed many different ways and are generally used as a method of
evaluation (Montgomery, 2000). Rubrics systematize what teachers already do mentally, which is to create evaluation criteria in their head then apply it to a piece of work (Montgomery, 2000). With a rubric the evaluation criteria becomes explicit and clear to the user (Jonsson & Svinghy, 2007; Luft, 1999).

Rubrics are both valuation tools and learning tools. They provide users with immediate, focused feedback on what they are evaluating (Jonsson & Svinghy, 2007; Montgomery, 2000). Rubrics that reflect and uncover problems users could encounter are especially useful (Andrade, 2000). The recommendations provided within the rubrics can easily be used to improve alignment and inform educators as they are interpreting the NGSS. Within this project rubric are defined as “an assessment tool that lists the criteria for a piece of work, or what counts, and articulates gradations of quality for each criterion, from excellent to poor” (Andrade, 2005, p. 27).

**Inter-rater Reliability**

A rubric is considered reliable if different people give the same pieces of work similar ratings (Andrade, 2005). In other words, when different people are using rubrics similar results should be obtained from scorers regardless of who they are, where they are, or when they use the rubric.

**Conclusion**

Knowledge about the NGSS and the research behind them is crucial to identifying SEPs and to designing a tool to help with this process. Without a tool, educators will need to spend time learning the standards and analyzing curriculum that is in place. This task could take any organization a number of years to complete. Developing a tool that is quick, accurate, and easy to use is challenging but necessary.
Chapter 3

Methodology

The goal of this project was to design a tool that enabled educators to quickly and easily identify Science and Engineering Practices (SEPs) in supplemental EE curriculum. This project was completed in four phases, (a) research, (b) design, (c) supplemental curriculum evaluation using EY, and (4) a pilot test to check for inter-rater reliability. Figure 2 summarizes and provides a timeline for the four phases.
**Figure 2.** Timeline and four phases of tool design.

<table>
<thead>
<tr>
<th>Phase 1: Background Research</th>
<th>Phase 2: Tool Design</th>
<th>Phase 3: Supplemental Curriculum Evaluation</th>
<th>Phase 4: Pilot Test</th>
</tr>
</thead>
</table>
| Knowledge and understanding of the Framework, NGSS, and EY Curriculum increased | Design sequence overview  
- Tool chosen: rubric  
- Three rubric categories emerge: explicit statement within the lesson, student actions, connections to DCIs and/or CCCs  
- Initial rubric-broad in scope, required NGSS Appendix F for use  
- Second Rubric-one rubric for each SEP, similar coversheet for each rubric  
- Quick reference guide and instructions developed  
- Third Rubric (after using rubrics on EY curriculum)-adjustments to rubric content and phrasing, additional clarification statements added  
- Fourth Rubric- teacher vs. student actions emphasized with additional directions and bolded font | EY curriculum evaluated by the author using SEP rubrics  
- Matrix containing EY lessons created to track SEPs by lesson (figure 9)  
- Recommendations for further alignment recorded (Appendix B)  
- Curriculum analyzed for SEP frequency (Table 1 and Figure 14) | Other science educators evaluated EY curriculum  
- Only Geology and Ecology lessons were evaluated by others  
- Seven science educators used the rubrics on EY curriculum  
- Reviewers had varying degrees of NGSS familiarity  
- Results from reviewers compared to results obtained by author (Figure 13) |

Resources used:
- *Ready, Set, Science!* (NRC, 2008a)
- *Taking Science to School* (NRC, 2008b)
- Front Matter and Appendices of NGSS (NRC, 2013)
- NGSS@NSTA website (www.ngss.nsta.org)
- *Translating the NGSS for Classroom Instruction* (Bybee, 2013)
- Numerous academic and practitioner journal articles
Phase 1: Research

Before product design, I acquainted myself with the Next Generation Science Standards (NGSS) and the research they were based on. I started by reading the NGSS Front Matter (NRC, 2013) and studying performance expectations (PEs), science and engineering practices (SEPs), crosscutting concepts (CCCs), and disciplinary core ideas (DCIs). This gave me a sense of how the standards were written and organized. Next, I read parts of the documents: *Taking Science to School* (NRC, 2007b), *Ready, Set, Science!* (NRC, 2007a), and the *Framework for K-12 Science Education (Framework)* (NRC, 2012). *Ready, Set, Science!* is a distillation of the research that was reported in *Taking Science to School* written in a more practical format specifically for science educators. A series of vignettes showcasing the research-based classroom practices described in the text accompany each chapter. When I needed more depth on a specific topic I referred back to the corresponding sections in *Taking Science to School* or the *Framework*. These two reports are based on the most current science teaching and learning research. I referenced them repeatedly as I familiarized myself with the NGSS.

The book of NGSS Appendices that accompanies the NGSS, was also vital to my understanding of the standards. The thirteen Appendices contain information on a variety of topics, including: conceptual shifts of the NGSS, learning progressions, and course sequencing examples for secondary schools. Appendices, E, F, and G, were the most beneficial to this project. They showed K-12 progressions for DCIs, SEPs, and CCCs (Figure 1). The progressions allow educators to see, if the NGSS were to be fully implemented, (a) what their students had been exposed to prior to their arrival in that particular grade level, (b) what they should be doing currently, and (c) what they are preparing them for in subsequent grade levels.
Appendix F, *Science and Engineering Practices in the NGSS*, became the backbone for the rubrics that were developed.

Books, journal articles, and the NGSS@NSTA website (www.ngss.nsta.org) were also instrumental in understanding the standards. Roger Bybee’s (2013) *Translating the NGSS for Classroom Instruction* was the most useful book for this project. Bybee’s book gives an overview of the standards and how to use them. It also contains sample lessons and vignettes that are aligned to the NGSS. Near the end of the book there are tools provided for aligning current instruction to the NGSS, which Bybee uses to take the reader through the thought process required for determining alignment.

Many journal articles also enhanced my understanding of the NGSS both as a whole and of specific SEPs. The National Science Teachers Association (NSTA) publications, *Science and Children*, *Science Scope*, and *The Science Teacher* published a number of articles focused on understanding the *Framework* and NGSS. These articles give readers a general introduction to the *Framework* (Pratt, 2011) and explain specific DCIs, SEPs, and CCCs (Bell, Bricker, Tzou, Lee, & Van Horne, 2012; Bybee, 2011, 2013; Krajcik & Merritt, 2012; Mayes & Koballa, 2012; Duschl, 2012; Reiser, Berland, & Kenyon, 2012; Sneider, 2012). There was another set of journal articles available regarding the use of specific SEPs. The NSTA journal articles were a starting point but in-depth explanations were found elsewhere (Bamberger & Davis, 2013; Berland & Hammer, 2012; Chin & Osborne, 2008; Sampson & Blanchard, 2012).

The NGSS@NSTA website offers users current information about the standards in the form of blogs, web seminars, and links related to NGSS (NSTA, 2014). The web seminars proved to be most helpful in understanding specific practices. These seminars detail each CCC
and SEP and most DCIs by describing the concept or practice and present classroom examples of its use at various grade levels.

**Phase 2: Tool Design**

After familiarizing myself with the standards I decided that a rubric would be a practical and familiar tool for educators. Rubrics are popular educational evaluation tools due to their ease of use; they are concise, digestible, and easy to explain (Andrade, 2000). This decision was also influenced by the tools in *Translating the NGSS for Classroom Instruction*, which presents several generic rubrics for judging alignment of lessons (Bybee, 2013). While these rubrics require the educator to have an understanding of all aspects of NGSS, I wanted to create something that allowed a new NGSS user to determine alignment of existing curriculum. Each rubric describes potential misuses of the scientific practice and provides ways to correct them. The feedback gleaned from the rubrics will help inform educators on how the practices are defined by the NGSS.

**Rubric design.** Rubric design began with an in-depth exploration of the SEPs. I identified the criterion needed for a lesson to be aligned regardless of a specific practice. From this exploration, three major themes emerged and became the evaluative criteria of the rubrics. They are: (a) explicit statement within the lesson, (b) student actions, and (c) connections to DCIs or CCCs. In order to be fully aligned with NGSS, based on the direction provided by the Framework, a lesson must meet criteria in each of these categories.

**Explicit statement.** Curriculum must be explicit in student goals and instructions. For this project, if a skill, activity, or set of directions is taught but not written then it will not be analyzed for alignment.
SEPs need to be explicit for this project, but also for the benefit of all curricula users. Supplemental curricula may be used by educators with varying levels of familiarity with NGSS. The standards were published less than a year ago, a short amount of time for educators to become familiar with a complex document. Some states have adopted the standards and others are in the adoption process. Educators are not required to align their curriculum to the NGSS until their state or district adopts the standards. Some educators will become familiar with the standards on their own and others will not. In a lesson fully aligned to NGSS the SEPs should be explicit and easy to identify, regardless of how familiar an educator is with NGSS.

**Student actions.** The SEPs are focused on what the student does, not what the teacher does. A lesson fully aligned to NGSS explicitly states that students will do the SEP. If a teacher does the SEP the lesson is not fully aligned. For example, in SEP #2: Developing and Using Models, one aspect of this SEP states that students will “develop a model using an analogy, example, or abstract representation to describe and/or predict phenomena” (NRC, 2013). Students are required to develop their own model and use it to describe or predict phenomena. If a teacher provides the model and students are using it to describe or predict phenomena, modeling is present in the lesson, but the lesson is not aligned to NGSS.

Although a lesson may not be aligned due to teacher involvement, this does not mean the lesson is not useful. Students do not innately know content or how to do the SEPs, they will need guidance at first. A lesson that is not fully aligned may serve as an important piece of scaffolding in helping students understand a concept or skill.

**Connections.** The NGSS focus on science and engineering as it is practiced and experienced in the real world. Each SEP must be connected to a DCI and/or CCC in order to be fully aligned (NRC, 2013). When discussing the SEPs, the NGSS states “practices alone are
activities and content alone is memorization…When SEPs and DCIs are integrated science begins to make sense and allows students to apply the material” (NRC, 2013).

NSTA is taking a similar stance. In a blog entry aimed at providing information on aligning curricular resources to NGSS, Ted Willard, Director of NGSS@NSTA, writes that he and other educators working on developing a portal for sharing NGSS aligned lessons follow a general rule, “at a minimum, for a resource to be considered aligned to NGSS, it must address at least one disciplinary core idea AND one scientific and engineering practice” (Willard, 2013). Without connections an SEP is just an activity and does not provide the necessary marriage of content and practice found in the real world of science and engineering.

Initial rubric. The first rubric developed was a one-page document that identified four areas crucial to alignment: (a) explicit statement within lesson, (b) age appropriateness, (c) doing the practice, and (d) connections (see Figure 3). In this version, educators would use the rubric in conjunction with Appendix F of the NGSS to determine if a lesson was aligned. Appendix F was used to judge age appropriateness, as all aspects of the EY lesson (in this project) fall within the 3-5 or 6-8 grade bands. This version was tested on the EY curriculum. After evaluating several lessons it was evident that the specifics of each SEP needed to be included on the rubric in order for other educators to be able to use it. The phrasing of several categories was vague and required a significant amount of knowledge about the SEPs and NGSS to be useful to an educator with little NGSS familiarity.
Second rubric. Before a new version of the rubric could be developed, I found I needed a deeper understanding about individual SEPs. To do this, I recorded the details of each SEP in a spreadsheet. Based on these details, I determined that the amount of information amassed could not be contained on a single rubric. In order to clearly communicate the ideas behind each practice eight individual rubrics were created, one for each practice.

The specifics of each SEP from the fourth through eighth grade level (EY participant grade levels) were examined. This proved to be very difficult as there are two NGSS grade bands (3-5 and 6-8) within the EY curriculum. The difference between what students should be able to do at the end of the 3-5 grade band and the end of the 6-8 grade band was different enough that two separate sets of rubrics would be needed.

Although EY serves the entirety of the 6-8 grade band, I choose to design a rubric based on the 3-5 grade band instead. This decision was based on my knowledge of the EY curriculum and timing of the release of NGSS in 2013. Following the release of the NGSS, it will necessarily be several years before all students are able to experience NGSS aligned curriculum from kindergarten to twelfth grade. In the first year post release, fourth through eighth grade students do not have the necessary background knowledge to successfully perform all SEPs at the correct grade band. In order for the EY curriculum to have the best chance at alignment, the
rubrics are based on the 3-5 grade band, with the knowledge that some lessons may include elements from grade bands above and below this. Ideally, rubrics for the 6-8 grade band will be created eventually and EY curriculum assessed on the alignment to that grade range as well. Due to the constraints of this project the construction of two sets of rubrics was not possible.

Once the grade band was identified, I began assembly of the second version of the rubrics (see Figure 4). Most information in this version of the rubrics came from the 3-5 grade band sections of Appendix F in the NGSS. Some information, mainly clarification statements and examples, came from NGSS related books or journal articles.
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scientific Questions</strong></td>
<td>The lesson does not include students identifying scientific (testable) and non-scientific (non-testable) questions.</td>
<td>In the lesson the teacher is identifying scientific (testable) and non-scientific (non-testable) questions for students. This could include students asking questions and the teacher classifying them. <strong>Recommendation:</strong> Alter the lesson so that students are classifying questions as scientific or non-scientific. OR The lesson does not explicitly state that students will identify scientific (testable) and non-scientific (non-testable) questions, but doing so is imperative to completing the lesson. <strong>Recommendation:</strong> Make this concept explicit by writing it into the lesson.</td>
<td>The lesson explicitly states that students will identify scientific (testable) and non-scientific (non-testable) questions.</td>
</tr>
<tr>
<td></td>
<td>The lesson does not give students the opportunity to ask questions that can be investigated (tested) or to predict reasonable outcomes for those questions.</td>
<td>In the lesson students are not given the opportunity to ask questions that can be investigated (tested), but are asked to predict reasonable outcomes (based on patterns) from a teacher-generated question. <strong>Recommendation:</strong> When the question is teacher generated students are not doing this aspect of the SEP, allow time in the lesson for students to come up with their own questions and predictions about phenomena. OR In the lesson students are asking questions that can be investigated (tested), but they are not predicting reasonable outcomes for their questions. <strong>Recommendation:</strong> Expand the lesson so that students are predicting reasonable outcomes based on patterns for their questions.</td>
<td>The lesson explicitly states that students will be asking questions that can be investigated (tested). Students will also predict reasonable outcomes for those questions based on patterns. (i.e., Cause and effect relationships, What happens to a plant when it kept in the dark? Prediction: I think the plant will die.)</td>
</tr>
</tbody>
</table>

*Figure 4.* Section from the second rubric for SEP #1: Asking Questions and Defining Problems.
Written versus enacted curriculum. One of the challenges in drafting these rubrics was establishing the difference between what the SEPs would look like written into a curriculum and what they would look like fully enacted in the classroom. Observing the SEPs in a classroom requires a different perspective than the one taken by this project. Several instruments have been developed to identify inquiry practices in science teaching, although none are specific to the NGSS’s SEPs (Forbes, Biggers, & Zangori, 2013).

The rubrics in this project do not give a description of student behavior and are not to be a checklist of activities. They focus on what is explicitly expressed in the written curriculum and are a method for determining if SEPs are present in existing supplemental curriculum. For the purposes of this project only curriculum text was analyzed, no consideration was given to how the lessons were actually enacted during EY programming.

The second draft rubrics were used to identify SEPs in two Geology and two Ecology lessons of the EY curriculum. Testing the rubrics allowed me to determine what changes needed to be made to the phrasing and construction of the rubric.

Based on the evaluation of this version, the largest change made was the addition of a Quick Reference Guide and coversheets for each rubric. These resources were created because determining which rubrics would be needed without a guide could be very cumbersome. In many cases I thought a lesson demonstrated a particular SEP but after using the rubric realize it was actually demonstrating another. For example, I assumed that a lesson that called for collecting and analyzing data would only align to SEP #4: Analyzing and Interpreting Data. It actually aligns to SEP #4 and SEP #3: Planning and Conducting Investigations.
Rubric coversheets. All coversheets follow the same layout, a series of three “yes” or “no” questions to help the user decide if a lesson contains a specific practice. A user must answer “yes” to all questions before moving on to the rubric.

Figure 5 is the coversheet for SEP #1: Asking Questions and Defining Problems. Question one always states the overall theme of the SEP. Question two lists three to five key student actions associated with the practice. The actions are broad summary statements derived from the fully aligned column of the rubrics. Question three is identical on all rubrics. It assures that the SEP is connected to a CCC and/or a DCI. As mentioned previously, an SEP by itself is an activity not a practice.
**SEP #1: Asking Questions and Defining Problems**  
Lesson Evaluation Rubric for 3rd-5th Grade

1) Are **student-generated** questions a part of this lesson?  
   OR  
   Are **students defining problems** as a part of this lesson?  
   
   If yes, continue to question 2.  
   If no, the SEP “asking questions and defining problems” is not present in this lesson.

2) Does the lesson state that **students** are doing at least one of the following?  
   a. Distinguishing between scientific (testable) and non-scientific (non-testable) questions  
   b. Asking questions that can be investigated (tested)  
   c. Asking questions about variables  
   d. Describing or defining solvable problems  
   
   If yes, continue to question 3.  
   If no, the SEP “asking questions and defining problems” is not present in this lesson or it is present at a different grade band.  
   Please see Appendix F of the NGSS for more information on grade band expectations.

3) Does the lesson connect to at least one 3rd-5th grade Disciplinary Core Idea (DCI) and/or one CCC (Crosscutting Concept)?  
   For a list of DCIs and CCCs please reference the NGSS available online at [www.nextgenscience.org](http://www.nextgenscience.org)  
   If yes, continue to the rubric.  
   If no, this lesson is not fully aligned to this SEP. A fully aligned lesson combines content and practice. Connect this lesson to a DCI and/or CCC for full alignment  
   
   In addition to answering yes to the first three questions a lesson must fall under “Fully Aligned” in at least one area of the rubric to be considered aligned to the NGSS.  
   
   If the lesson does not contain any aspects in the “Fully Aligned” column it is not considered aligned to the NGSS.  
   
   Follow the recommendations in the “Partially Aligned” column to help align the lesson. These are often small shifts within the lesson.

*Figure 5.* Rubric coversheet for SEP #1: Asking Questions and Defining Problems.
Quick reference guide. The coversheets helped me choose the correct rubric but were not efficient. If I were unsure of what practices were specifically included in a SEP I had to shuffle through pages of rubrics until I found the coversheet I needed. This lead to the design of the SEP Reference Sheet (Figure 6 and Appendix A). With the aid of the SEP Quick Reference Guide I was able to quickly identify which practices were most likely present in a lesson and know which rubrics I would be working with.

The left-hand column of the reference sheet lists the attributes of SEPs at the 3-5 grade band by topic, not by SEP. Some attributes appear in more than one topic and topics may contain attributes from several SEPs. For example, Figure 6 shows the topic “Planning or conducting investigations” and lists seven attributes from three different SEPs. The middle column designates the number and name of the SEP rubric that should be used for each attribute. The right-hand column lists where on the rubric the attribute will be found. Each fully aligned of the rubric has a number and letter designation, for example 3c. These designations were added to the third version of the rubric. They are found in the “Use rubric square” column of the Quick Reference Guide (Figure 6) and appear in bold letters in the rubrics before the text in the “fully aligned” column (B1 Figure 7).
<table>
<thead>
<tr>
<th>Attributes</th>
<th>Use SEP Rubric</th>
<th>Use rubric square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking questions that can be investigated (tested)</td>
<td>#1: Asking questions and defining problems</td>
<td>1a</td>
</tr>
<tr>
<td>Using a model to test relationships or interactions within a system</td>
<td>#2: Developing and Using Models</td>
<td>2c</td>
</tr>
<tr>
<td>Planning and conducting investigations</td>
<td>#3: Planning and Carrying Out Investigations</td>
<td>3a</td>
</tr>
<tr>
<td>Producing and/or collecting data</td>
<td>#3: Planning and Carrying Out Investigations</td>
<td>3b/3c</td>
</tr>
<tr>
<td>Making observations</td>
<td>#3: Planning and Carrying Out Investigations</td>
<td>3c</td>
</tr>
<tr>
<td>Making predictions</td>
<td>#3: Planning and Carrying Out Investigations</td>
<td>3d</td>
</tr>
<tr>
<td>Testing different models of the same object, tool, or process</td>
<td>#3: Planning and Carrying Out Investigations</td>
<td>3e</td>
</tr>
</tbody>
</table>

*Figure 6. Topic and attributes from the SEP Quick Reference Guide.*
<table>
<thead>
<tr>
<th>A</th>
<th>B1</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scientific Questions</strong></td>
<td><strong>Fully Aligned</strong></td>
<td><strong>Partially Aligned</strong></td>
<td><strong>Not Aligned</strong></td>
</tr>
<tr>
<td>Clarification Statement: Scientific questions are questions about phenomena that can be tested, by doing an experiment, to help us develop explanations for the phenomena. Testable questions are not opinion based (e.g., Which flower is the prettiest? Is not a scientific testable question)</td>
<td>(1a) The lesson explicitly states that students will identify scientific (testable) and non-scientific (non-testable) questions.</td>
<td>In the lesson the teacher is identifying scientific (testable) and non-scientific (non-testable) questions for students. This could include students asking questions and the teacher classifying them. <strong>Recommendation:</strong> Alter the lesson so that students are classifying questions as scientific or non-scientific. OR The lesson does not explicitly state that students will identify scientific (testable) and non-scientific (non-testable) questions, but doing so is imperative to completing the lesson. <strong>Recommendation:</strong> Make this concept explicit by writing it into the lesson.</td>
<td>The lesson does not include students identifying scientific (testable) and non-scientific (non-testable) questions.</td>
</tr>
<tr>
<td>Example: Testable: What is the density of an apple? Non-testable: Which apple tastes the best?</td>
<td>(1b) The lesson explicitly states that students will be asking questions that can be investigated (tested). Students will also predict reasonable outcomes for those questions based on patterns. (i.e., Cause and effect relationships: What happens to a plant when it kept in the dark? Prediction: I think the plant will die.)</td>
<td>In the lesson students are not given the opportunity to ask questions that can be investigated (tested), but are asked to predict reasonable outcomes (based on patterns) from a teacher-generated question. <strong>Recommendation:</strong> When the question is teacher generated students are not doing this aspect of the SEP, allow time in the lesson for students to come up with their own questions and predictions about phenomena. OR In the lesson students are asking questions that can be investigated (tested), but they are not predicting reasonable outcomes for their questions. <strong>Recommendation:</strong> Expand the lesson so that students are predicting reasonable outcomes based on patterns for their questions.</td>
<td>The lesson does not give students the opportunity to ask questions that can be investigated (tested) or to predict reasonable outcomes for those questions.</td>
</tr>
</tbody>
</table>

*Figure 7.* Section from a third draft rubric for SEP #1: Asking Questions and Defining Problems.
Rubric instructions. Rubric instructions (Appendix A) were written after the Quick Reference Guide was developed. I used the Quick Reference Guide, coversheets, and rubrics to align two EY lessons. While using the rubrics I noted every step performed with as much detail as possible. These notes were edited and became the first set of instructions. The instructions were tested on the same EY lessons, revised, and tested again. Trial and revision occurred numerous times before the final version of instructions was compiled. At various times during this process other science education graduate students used the instructions on EY lessons and made suggestions for revision.

Third rubric. In the third rubric (Figure 7) the phrasing in some of the rubrics was changed to better reflect the practice and/or make the SEP easier to identify in written curriculum. Based on feedback from other science education graduate students clarification statements were added to column A (Figure 7). These statements define language specific to NGSS and commonly misused science words, such as theory or hypothesis. Some clarification statements give examples of the SEP or how the practice could be used.

The second version rubric introduced the negative “Not Aligned” criteria first when reading the rubric from left to right (column B, Figure 6). I wanted the rubrics to introduce the positive “Fully Aligned” criteria first (column D, Figure 6). The third version (Figure 7) moved the “Not Aligned” criteria to column D and the “Fully Aligned” criteria to column B. This allowed users to determine what fully aligned lessons included without reading through the not aligned and partially aligned criteria.

Fourth rubric. The fourth and final version of the rubrics (Figure 8 and Appendix A) contained only minor changes. These changes were made at the end of the project after the pilot
test for inter-rater reliability. Changes were made based on the recommendations of reviewers and the differences between the author’s and reviewers’ results.
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
<tr>
<td><strong>Scientific Questions</strong></td>
<td>Fully Aligned</td>
<td>Partially Aligned</td>
<td>Not Aligned</td>
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<tr>
<td>Clarification Statement: Scientific questions are questions about phenomena that can be tested, by doing an experiment, to help us develop explanations for the phenomena. Testable questions are not opinion based (e.g., Which flower is the prettiest? Is not a scientific testable question)</td>
<td>In the lesson the <strong>teacher</strong> is identifying scientific (testable) and non-scientific (non-testable) questions for students. This could include students asking questions and the teacher classifying them. <strong>Recommendation:</strong> Alter the lesson so that students are classifying questions as scientific or non-scientific. OR The lesson does not explicitly state that <strong>students</strong> will identify scientific (testable) and non-scientific (non-testable) questions, but doing so is imperative to completing the lesson. <strong>Recommendation:</strong> Make this concept explicit by writing it into the lesson.</td>
<td><strong>Example:</strong> Testable: What is the density of an apple? Non-testable: Which apple tastes the best?</td>
<td>The lesson does not include students identifying scientific (testable) and non-scientific (non-testable) questions.</td>
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<tr>
<td>(1a) The lesson explicitly states that <strong>students</strong> will identify scientific (testable) and non-scientific (non-testable) questions.</td>
<td></td>
<td>In the lesson <strong>students are not given the opportunity</strong> to ask questions that can be investigated (tested), but are asked to predict reasonable outcomes (based on patterns) from a teacher-generated question. <strong>Recommendation:</strong> When the question is teacher generated students are not doing this aspect of the SEP, allow time in the lesson for students to come up with their own questions and predictions about phenomena. OR</td>
<td>The lesson does not give students the opportunity to ask questions that can be investigated (tested) or to predict reasonable outcomes for those questions.</td>
</tr>
<tr>
<td>(1b) The lesson explicitly states that <strong>students</strong> will be asking questions that can be investigated (tested). <strong>Students</strong> will also predict reasonable outcomes for those questions based on patterns. (i.e., Cause and effect relationships: What happens to a plant when it kept in the dark? Prediction: I think the plant will die.)</td>
<td></td>
<td>In the lesson <strong>students</strong> are asking questions that can be investigated (tested), but they are not predicting reasonable outcomes for their questions. <strong>Recommendation:</strong> Expand the lesson so that students are predicting reasonable outcomes based on patterns for their questions.</td>
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</table>

*Figure 8.* Section from the final draft rubric for SEP #1: Asking Questions and Defining Problems. The final version differs from version three by adding emphasis on student versus teacher actions.
Phase 3: Curriculum Evaluation

The third version of rubrics were used to evaluate the EY curriculum. A matrix of EY lessons and SEPs was created to keep track of the practices present by lesson (Figure 9). Analysis was conducted to evaluate the curriculum as a whole and identify where SEPs were present.

The next step required an in-depth review of the lessons. Each lesson was analyzed using the instructions, Quick Reference Guide, and the rubrics (Appendix A). I created detailed notes, which included where the lesson fell on each rubric, the evidence (or lack of) alignment, and what connections to DCIs and/or CCCs were present. If a lesson was partially aligned, I recorded what needed to be changed to increase alignment to fully aligned. The recommendations for increased alignment were compiled into a chart (Figure 10 and Appendix B).
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<td>Through the Ages</td>
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<td>Waters of Life</td>
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</tbody>
</table>

*Figure 9. Blank EY lesson matrix.*
<table>
<thead>
<tr>
<th>Lesson</th>
<th>Fully Aligned SEPs</th>
<th>Partially Aligned SEPs</th>
<th>Recommendations for Full Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through the Ages</td>
<td>SEP #2: Developing and Using Models</td>
<td>SEP #6: Constructing Explanations and Designing Solutions</td>
<td>In the discussion in activity 3, require students to use evidence when looking at YNP through time. Emphasize the “why?” Students can use their journal entries from the previous activities as evidence.</td>
</tr>
<tr>
<td>Landscaping with Wind &amp; Water</td>
<td>SEP #2: Developing and Using Models SEP #3: Planning and Carrying Out Investigations</td>
<td>SEP #1: Asking Questions and Defining Problems</td>
<td>Before students erode their landscape have them develop testable questions relating to erosion.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SEP #6: Constructing Explanations and Designing Solutions</td>
<td>In Activity 2 when interviewing a tree, have the student that is the tree answer the questions using physical evidence on or near the tree, not just their imagination.</td>
</tr>
</tbody>
</table>

*Figure 10.* Recommendations for increased alignment to NGSS for two EY Geology lessons.
Curriculum analysis. The EY curriculum was analyzed as a whole to understand where individual SEPs were concentrated or absent. Frequency of individual SEPs was calculated using the EY matrix.

Phase 4: Inter-rater reliability

Seven science educators tested the rubrics: two graduate students in science education, four current teachers, and one faculty member at the University of Wyoming. Three reviewers had little or no NGSS familiarity, three reviewers had high NGSS familiarity, and one reviewer had very high familiarity with NGSS. Each reviewer was given a section of EY curriculum rubrics and instructions, and an evaluation form to report results and give feedback. Feedback was used to make final adjustments to the rubrics. This project must have inter-rater reliability to be useful to other educators. If there is not inter-rater reliability different users will interpret the same lessons differently, which is what this project is trying to prevent.

The author’s analysis was compared to the reviewers’ evaluation to determine inter-rater reliability. The results of the author and reviewers were placed into an EY matrix and color-coded based on the number of reviewers and SEPs chosen.
Chapter 4

Results

The NGSS’s science and engineering practices (SEPs) can be identified within existing supplemental curricula. The use of specific tools makes this process more efficient. The tools designed in this project (as described in the methodology) are the SEP Quick Reference Guide and SEP coversheets and rubrics complied into a booklet (Appendix A).

Final Draft

The final version of the rubrics is slightly different from the version that reviewers used. After receiving feedback and seeing reviewers’ results additional references were added and student/teacher actions were emphasized. Figure 11 is an example of a final SEP rubric.

A lesson fully aligned to an SEP must be aligned to at least one CCC and/or DCI for third-fifth grade. A list of CCCs and the DCIs for the 3-5 grade band are provided at the end of the booklet. Figure 12 is an example of a part of this list.

Most of the time, the difference between a fully aligned and partially aligned lesson depends on who is doing the SEP. In a fully aligned lesson it is the student, in a partially aligned lesson it is the teacher. The words “student” and “teacher” were bolded and underlined to emphasize this distinction (Figure 11).
### SEP #6: Constructing Explanations and Designing Solutions

#### Lesson Evaluation Rubric for 3rd-5th Grade

<table>
<thead>
<tr>
<th>Constructing Explanations</th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarification Statement:</td>
<td></td>
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</tr>
<tr>
<td>In this SEP an explanation links a scientific theory with scientific observations or phenomena, it is a causal explanation that identifies the underlying chain of cause and effect (NRC, 2012).</td>
<td>(6a) The lesson explicitly states that students will construct an explanation of a phenomena based on observed relationships. (i.e. constructing an explanation for the distribution of plants in a backyard).</td>
<td>The teacher provides an explanation of phenomena for students based on observed relationships. Recommendation: Allow students to come up with their own explanations. OR The lesson states that students will construct an explanation but it is not based on observations or the basis for the explanation is not explicitly written in the lesson. Recommendation: Make it explicit by adding to the lesson the basis for the explanation (observed relationships).</td>
<td>The lesson does not give students the opportunity to construct an explanation.</td>
</tr>
<tr>
<td>Using Evidence</td>
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<tr>
<td>(6b) The lesson explicitly states that students will construct or support an explanation or design a solution to a problem by using evidence (i.e., measurements, observations, patterns).</td>
<td>In the lesson students are constructing or supporting explanations or designing a solution to a problem but not using evidence (e.g., measurements, observations, patterns) or the use of evidence is implied, not explicitly stated. Recommendation: Make this explicit by specifying the use of evidence when constructing or supporting explanations or when designing a solution.</td>
<td>In the lesson students are not constructing or supporting an explanation OR they are not designing a solution to a problem.</td>
<td></td>
</tr>
<tr>
<td>(6c) The lesson explicitly states that students will be presented with an explanation and asked to identify the evidence that supports specific points within it.</td>
<td>In the lesson the teacher identifies evidence that supports specific points of an explanation for students. Recommendation: Allow students to identify the evidence. OR In the lesson students are presented with an explanation but are not explicitly asked to identify the evidence that supports specific points. This may be implied and/or imperative to the completion of the lesson, but not stated. Recommendation: Make this explicit by adding to the lesson the basis for the explanation.</td>
<td>In the lesson students are presented with an explanation but they are not asked to identify the evidence that supports it.</td>
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<tr>
<td>Solving Design Problems</td>
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<tr>
<td>Clarification Statements:</td>
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<tr>
<td>Criteria-what is required for the solution to be successful. Constraints-things that limit a solution such as time, materials, or cost.</td>
<td>(6d) The lesson explicitly states that students will apply their knowledge of science to solve design problems.</td>
<td>In the lesson students are using their knowledge of science to solve design problems, but it is not explicitly stated in the lesson. Recommendation: Make the use of scientific knowledge explicit in the lesson.</td>
<td>In the lesson students are not solving design problems.</td>
</tr>
<tr>
<td>(6e) The lesson explicitly states that students will come up with multiple solutions to a problem. They will also compare these solutions based on how well they meet the established criteria and constraints of the problem.</td>
<td>In the lesson students will come up with multiple solutions to a problem, but will not compare solutions based on how well they meet the criteria and constraints of the design problem. Recommendation: Make comparing solutions based on how well they meet the established criteria and constraints of the design problem a part of the lesson. OR In the lesson students evaluate a single solution on how well it meets criteria and constraints. Recommendation: Have students generate more than one solution. Instead of evaluating a single solution, evaluate multiple.</td>
<td>In the lesson students will come up with only one solution to a problem.</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 11.** Final version of the lesson evaluation rubric for SEP #6: Constructing Explanations and Designing Solutions.
Disciplinary Core Ideas for Grades 3-5

More information and a complete description of DCIs can be found at http://www.nextgenscience.org/search-standards-dci

3rd Grade
Physical Science
PS2.A: Forces and Motion
PS2.B: Types of Interactions
Life Science
LS1.B: Growth and Development of Organisms
LS2.C: Ecosystem Dynamics, Functioning, and Resilience
LS2.D: Social Interactions and Group Behavior
LS3.A: Inheritance of Traits
LS3.B: Variation of Traits
LS4.A: Evidence of Common Ancestry and Diversity
LS4.B: Natural Selection
LS4.C: Adaptation
LS4.D: Biodiversity and Humans
Earth Systems Science
ESS2.C: The Role of Water in Earth’s Surface Processes
Engineering Design
ETS1.A: Defining and Delimiting Engineering Problems
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution

Figure 12. List of disciplinary core ideas for third grade found in the additional resources section of Appendix A. A similar list exists for fourth and fifth grades.
Expedition: Yellowstone! (EY) Curriculum Evaluation

The rubrics were piloted using the EY curriculum; what follows is a description of the results of this evaluation. All SEPs were found to be present in the curriculum. Figure 13 is a matrix showing SEPs identified by lesson. SEP #8: Obtaining, Evaluating, and Communicating Information appeared most often, found to be present in 16 of 35 lessons. SEP #1: Asking Questions and Defining Problems and SEP #7: Engaging in Argument from Evidence were present the least often only appearing in two of 35 lessons. Table 1 summarizes these results.

Many lessons were partially aligned to an SEP. Recommendations gleaned from the rubrics, as described in the methodology, to improve the alignment of these lessons are provided in Appendix B.
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<td>Your Park–Your Responsibility</td>
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<td>X</td>
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<td>You Be the Judge</td>
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<td>Yellowstone in Time</td>
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<tr>
<td>Chants of a Lifetime</td>
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<td>X</td>
<td></td>
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<tr>
<td>Sharing a Story</td>
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<td>Trappers, Traders, &amp; Top Hats</td>
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<td></td>
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<td>The Nation Cries Out</td>
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<td>Speak Loudly &amp; Carry a Big Stick</td>
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<tr>
<td>Expressing the Wonders</td>
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<td>X</td>
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<tr>
<td>Unit 3: Geologic Wonders</td>
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<tr>
<td>Through the Ages</td>
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<td>Landscaping with Wind &amp; Water</td>
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<td>X</td>
<td>X</td>
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<td>Unit 4: Ecological Communities</td>
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<td>Who Am I?</td>
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<td>X</td>
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<td>To Prey or Not to Prey</td>
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<td>X</td>
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<td>Tell-Tale Animal Signs</td>
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<td>X</td>
<td></td>
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<tr>
<td>Whose Teeth are These?</td>
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<td>X</td>
<td></td>
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<td>Invent an Animal</td>
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<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>X</td>
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<td>Recording Wildlife</td>
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<td>X</td>
<td>X</td>
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<td>Making Tracks</td>
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<td>Winter Survival</td>
<td>X</td>
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<td>Wild Wapiti</td>
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<td>X</td>
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<td>On Fire!</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Out of the Fire</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<td></td>
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<tr>
<td>Talking Trees</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waters of Life</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<td></td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2</strong></td>
<td><strong>10</strong></td>
<td><strong>11</strong></td>
<td><strong>12</strong></td>
<td><strong>6</strong></td>
<td><strong>11</strong></td>
<td><strong>2</strong></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>

*Figure 13.* Expedition: Yellowstone! curriculum evaluation results by lesson. An "X" indicates the author found the lesson to be fully aligned to the corresponding science and engineering practice (SEP) listed across the top of the table.
### Table 1

**Frequency of Science and Engineering Practices (SEPs) by Unit in the Expedition: Yellowstone! Curriculum**

<table>
<thead>
<tr>
<th>SEP 1: Asking Questions &amp; Defining Problems</th>
<th>Unit 1: Yellowstone’s Legacy (7 lessons)</th>
<th>Unit 2: Voices from the Past (10 lessons)</th>
<th>Unit 3: Geologic Wonders (3 lessons)</th>
<th>Unit 4: Ecological Communities (15 lessons)</th>
<th>All Units (35 lessons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEP 2: Developing &amp; Using Models</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>SEP 3: Planning &amp; Carrying Out Investigations</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>SEP 4: Analyzing &amp; Interpreting Data</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>SEP 5: Using Mathematics &amp; Computational Thinking</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>SEP 6: Constructing Explanations &amp; Designing Solutions</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>SEP 7: Engaging in Argument from Evidence</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>SEP 8: Obtaining, Evaluating, &amp; Communicating Information</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>10</td>
<td>16</td>
</tr>
</tbody>
</table>
Inter-rater Reliability

Thirteen of the eighteen science-based EY lessons were reviewed by others in a pilot test to check for inter-rater reliability. Reviewers rated themselves as having low, high, or very high NGSS familiarity. Due to the number of and time constraints of reviewers not all lessons were reviewed by someone from each level of familiarity and only the science lessons were reviewed. Of the thirteen lessons: all were reviewed by the author, nine lessons were analyzed by reviewers with no familiarity with NGSS, eight lessons were analyzed by reviewers with high NGSS familiarity, and three lessons were analyzed by a reviewer with very high NGSS familiarity. Figure 14 details these results.

The reviewer with very high NGSS familiarity identified the same SEPs as the author in the lessons they reviewed. The low familiarity and high familiarity groups only sometimes identified the same SEPs as the author.
Figure 14. Identification of science and engineering practices (SEPs) in 13 Expedition: Yellowstone! lessons by all reviewers. Each letter represents one reviewer.
Chapter 5

Discussion

This project sought to determine how to identify science and engineering practices (SEPs) within existing written EE supplemental curricula. In doing so, the latest science education research was used to develop a set of rubrics that determined alignment to the Next Generation Science Standards (NGSS). The development of these rubrics and associated materials (Appendix A) addresses the first two research questions: How can scientific and engineering practices be identified within existing supplemental EE curricula? and How can the latest research on science education be used to develop a tool that determines alignment of written curriculum to the NGSS, specifically to the scientific and engineering practices? Additionally, the following section discusses potential limitations of the NGSS I found as developing the rubrics.

I will re-address the final two research questions in the following ways: First, I will explain my findings from using the rubrics to analyze the Expedition: Yellowstone! (EY) supplemental curricula. This is related to my third research question: What science and engineering practices are represented in the EY curriculum? Second, I will discuss the results of the pilot study where other science educators used the rubrics with EY curriculum. This is related to my final research question: Can others use this tool to achieve similar results as the author?

Developing the Rubrics: Limitations of the NGSS

In this project, developing the rubrics led to two key observations about the NGSS observation is not an explicit skill in the SEPs and (b) lessons that are fully aligned tend to be more student directed.
**Observation.** Observation is an important scientific practice that deserves more attention in the NGSS. It is nearly impossible to develop or revise questions or plan and conduct investigations without using observation skills. These skills must be developed in students, however, they are treated as a fully-developed skill in the SEPs. For example, they are secondary skills used to support other SEPs. In the 3-5 grade band, observation is referred to most of the time as “evidence” or “data” and only once as “observation” (NRC, 2013, p. 6 & 10). The K-2 grade band explicitly focuses on making observations. In SEP #4: Analyzing and Interpreting Data it states that students will,

- Record information (observations, thoughts, and ideas)…. use and share pictures, drawings, and/or writings of observations…use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions or solve problems. (NRC, 2013, p. 9)

The 3-5 grade band builds on these skills, but does so implicitly. In SEP #1: Asking Questions and Defining Problems at the K-2 level students will, “ask questions based on observations to find more information about the natural and/or designed world(s)” (NRC, 2013, p. 4). Further, in the 6-8 and 9-12 grade band students will, “ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information” (NRC, 2013, p. 4). However, there is no mention of using observation to ask questions in the 3-5 grade band. I believe that more attention should be given to how to make those “careful observations” in the 3-5 grade band across all of the SEPs (NRC, 2013, p.4).

**Teacher involvement.** A lesson fully aligned to any SEP tends to be student-centered with little teacher involvement. This is similar to open inquiry where students have the most opportunity to behave like a community of scientists by asking their own questions, designing
their own experiments, and communicating their results. This level of student control requires the most scientific reasoning and greatest cognitive demand (Banchi & Bell, 2008). It is neither possible nor advisable for all lessons to be at this level of inquiry, especially for elementary students. Students need extensive practice to develop their inquiry skills and understandings until they are able to conduct their own investigation from beginning to end (Banchi & Bell, 2008). Because of this, lessons that are not considered fully aligned should not be discarded. They may act as necessary scaffolding for students as they are developing the capacity to accomplish a skill on their own.

**Using the Rubrics to Evaluate the Expedition: Yellowstone! Curriculum**

While SEP #1: Asking Questions and Defining Problems and SEP #7: Engaging in Argument from Evidence only appeared twice across 35 lessons (Table 1), this does not necessarily mean that the curriculum overall is lacking. A curriculum should be looked at as a whole, not only by individual lessons. It is also important to remember that not every practice needs to be in every lesson; doing so would be overwhelming for students and teachers. Even though these practices were sparse, they were present and overall the EY curriculum was fully aligned to all SEPs.

**Asking questions.** EY and REE experiences in general spark student curiosity and provide opportunity for questions to be asked. Student questions should be highlighted and they be given explicit time to work on them. In several science-based lessons (*Landscaping with Wind and Water, Testing the Waters, Waters of Life*) it would be easy to add explicit instructions guiding students to come up with answerable or testable questions they would like to investigate before the lesson or talk about additional questions they could investigate based on what they found in the lesson. Figure 15 is an example recommendation for an EY lesson that could be
aligned to SEP #1: Asking Questions and Defining Problems. Appendix B contains more details regarding recommendations for alignment of the EY curriculum.

Asking scientific questions may be a skill that is not well developed in this curriculum due to the short duration and varied science background of students. EY participants bring with them varying degrees of science knowledge and trip preparation. The ability to identify and develop testable questions is a skill developed over time and cannot be fully grasped by 4th-8th graders in only a few lessons.

**Argumentation.** Engaging in argument from evidence was present within the EY curriculum, but not fully aligned in any of the lessons. In a fully aligned lesson students make a claim and support it with evidence. In the EY curriculum students make claims but the use of evidence is not required or implied. Making this use of evidence explicit will move the curriculum from partially aligned to fully aligned.

**Partial Alignment**

Nineteen lessons contained partially aligned SEPs. This may be due to nature of the EY units, the constraints of the EY program, and the student directed nature of the SEPs. EY curriculum contains two human history units (n=17 lessons) and two science units (n=18 lessons). Since half of the curriculum focuses on human history, these lessons cannot be expected to be fully aligned to the SEPs. The *Framework* stated specifically that the social sciences were purposefully left out of the NGSS (NRC, 2012).
**Figure 15.** Recommendations for *Waters of Life* Expedition: Yellowstone! lesson. This lesson could be aligned to SEP #1: Asking Questions and Defining problems with a small change, listed in the "Recommendations for Full Alignment" column.

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Fully Aligned SEPs</th>
<th>Partially Aligned SEPs</th>
<th>Recommendations for Full Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waters of Life</td>
<td>SEP #2: Developing and Using Models</td>
<td>SEP #1: Asking Questions and Defining Problems</td>
<td>Before the lesson have students generate testable questions about riparian areas and predict the answers to their questions.</td>
</tr>
<tr>
<td></td>
<td>SEP #3: Planning and Carrying Out Investigations</td>
<td>SEP #6: Constructing Explanations and Designing Solutions</td>
<td>At the end of the activity when asking what connections can be made between aquatic and riparian plant and animal communities, ask students to explain their reasoning using evidence from their investigation.</td>
</tr>
</tbody>
</table>
**Program constraints.** EY is a 4-5 day REE experience, and many students who participate in EY are not familiar with Yellowstone National Park or the science concepts in the curriculum. A lack of prior knowledge about their surroundings makes it difficult for lessons to be completely student driven. For example, if students were planning an investigation about the biodiversity of Yellowstone they would need to decide what data to record, how to record it, and where to collect it. In order to accomplish the goals of the program from the park rangers’ and teachers’ perspectives in a short amount of time, some activities necessarily need to be more ranger directed than student directed. These lessons can provide skills the teacher can build on after the trip. For students who have never designed an investigation this process may be overwhelming and would require significant teacher support. While students can conduct their own research, without significant prior support, as exemplified in the EY STaRRS program (Houseal, 2014), that would take valuable time out of the program that students could be outdoors exploring YNP. When the question and methods are provided students can still get the experience of collecting and analyzing data, making conclusions, and presenting their results.

**Facilitating Discussions**

With the EY lessons, a ranger or teacher is often asked to facilitate a discussion about a topic. Discussion is a common term that is often not well defined. A teacher could interpret discussion to mean “a recitation where he or she does most of the talking, a one-on-one conversation with a student, or a Socratic seminar where he or she says almost nothing at all” (Juzwik, Borsheim-Black, Caughlan, & Heintz, 2013, p. 9). The EY curriculum provides little guidance for teacher or ranger led discussions. A student may be participating in an SEP (mainly, engaging in argument from evidence or constructing explanations) depending on how
the instructor facilitates the conversation. There is an opportunity to increase SEP alignment, as well as Common Core State Standards (CCSS) alignment by providing some general discussion guidelines. In both the NGSS and CCSS for English-Language Arts students are required to use evidence to support their claims and contribute to discussion (NRC, 2013; National Governors Association Center for Best Practices [NGA Center] & Council of Chief State School Officers [CCSSO], 2010). When a lesson calls for a discussion the use of evidence by students should be made explicit.

**Inter-rater Reliability**

The results of the author and six reviewers did not match as closely as anticipated. The reviewer with very high NGSS familiarity was the only reviewer to identify the same SEPs as the author. Other reviewers only sometimes matched the author’s results. There was no evidence indicating that self identified people with high familiarity reviewers matched the author more than those who self identified as low familiarity reviewers. This could mean several things, (a) some of the reviewers who answered with “high NGSS familiarity” were not as familiar as they thought or reviewers who ranked themselves as “low NGSS familiarity” were more familiar than they realized, (b) reviewers from both groups did not follow directions, or (c) the directions were unclear causing reviewers to identify SEPs differently from the author. More data are needed from reviewers to understand the differences in results.

The NGSS have only been in existence for one year and rubrics suggest what it will take to achieve full alignment. In addition, the rubrics are still in a pilot phase and this project explored the possibility for them to produce repeatable results. More work is needed on many aspects of the rubrics. They will require many more revisions and rounds of piloting before validity and reliability are established.
Project Limitations

This project focused exclusively on the written EY curriculum, not what was actually taught during an EY lesson. The EY curriculum is ten years old and lesson content has gradually changed over time. Analyzing EY programming as it occurs in the field could provide a more accurate assessment of SEP alignment. However, the rubrics are written to analyze a written, not enacted, version of a curriculum. There is a possibility that they could eventually be modified to measure student or teacher behaviors, however this was outside of the scope of this project. The SEP rubrics were created based on the NGSS and associated research. They were tested on one supplemental REE curriculum. In order to be applicable for other curricula further trials evaluating different curricula are necessary.

The differences between the author and reviews’ alignment results were too great to assume that this tool will consistently produce accurate results at this point in time. The rubrics and instructions need to be refined then piloted with a broader audience repeatedly to determine the conditions for reliability and validity.

Conclusions

EY and other REE curricula need to be aligned to standards to gain credibility with administrators, teachers, and parents. The tools developed in this project have the potential to help them achieve alignment. An EY curriculum analysis found all SEPs to be present and fully aligned within the entire curriculum. Many lessons were also partially aligned and with small adjustments could be fully aligned.

The EY analysis also provided evidence that science and engineering practices can be identified within existing curriculum with the use of these rubrics and guides. These documents used the latest research on science education to help educators judge alignment of existing
written curriculum. When other science educators used the tools on EY lessons they found them quick and easy to use, but the rubrics did not produce similar results from each reviewer who used them. More revisions and testing are necessary before they can be considered a valid and reliable method for determining NGSS alignment.

**Recommendations for Further Research**

In the future a study to determine the reliability and validity of the rubrics would be highly beneficial. Determining reliability would entail a larger sample size and a population of educators with a wide range of NGSS familiarity. Also, the number and type of lessons reviewed should be expanded beyond the EY curriculum. Validity will also need to be explored to understand how closely the rubrics match the content of the NGSS.

The rubrics in this project focused on the SEPs and the 3-5 grade band. I would like to develop similar SEP rubrics for all grade bands. This could help educators at any level determine alignment to SEPs. I would also like to develop rubrics for crosscutting concepts (CCCs) at all grade levels. Based on my experiences with teachers thus far, CCCs are already being overlooked as they try to understand and incorporate SEPs and disciplinary core ideas (DCIs) into their classrooms. The CCCs are an important part of the NGSS and rubrics to identify them could help educators be more explicit about their CCC implementation.


Appendix A

Science and Engineering Practices (SEPs) Rubrics and Associated Materials
Scientific and Engineering Practices (SEP) in the Next Generation Science Standards

Rubrics for grades 3-5
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Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
How to Use the NGSS Science and Engineering Practices Rubrics

1) A lesson may contain none, one, or several SEPs. If you already know the practice(s) that may be in the lesson find the correct rubric and skip to step 3.

<table>
<thead>
<tr>
<th>Rubric/SEP #</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Asking Questions and Defining Problems</td>
</tr>
<tr>
<td>2</td>
<td>Developing and Using Models</td>
</tr>
<tr>
<td>3</td>
<td>Planning and Carrying Out Investigations</td>
</tr>
<tr>
<td>4</td>
<td>Analyzing and Interpreting Data</td>
</tr>
<tr>
<td>5</td>
<td>Using Mathematics and Computational Thinking</td>
</tr>
<tr>
<td>6</td>
<td>Constructing Explanations and Designing Solutions</td>
</tr>
<tr>
<td>7</td>
<td>Engaging in Argument from Evidence</td>
</tr>
<tr>
<td>8</td>
<td>Obtaining, Evaluating, and Communicating Information</td>
</tr>
</tbody>
</table>

2) If you do not know the practice(s) that may be in the lesson go to the SEP Quick Reference Guide. The SEP Quick Reference Guide lists the attributes of all eight practices broken into categories. Some categories contain attributes from more than one practice and some attributes are found in more than one category.
   a. Find the category or categories that best represent what students are doing in the lesson.
   b. Within the category, find the attribute(s) that best represent what students are doing in the lesson.
   c. The right column “Use SEP Rubric” tells you which rubric(s) will be needed.
   d. The left column corresponds to a “fully aligned” box in the rubric. This number/letter combination allows you quickly find the part of the rubric that corresponds to what is being done in the lesson.

3) Begin with page 1, the coversheet for the rubric. Answer the 3 questions in order.
   a. If any of the questions are answered with “no” that SEP is not explicit in the lesson.
   b. If the 3 questions can all be answered with “yes” then proceed to page 2.

4) Page 2 begins the actual rubric. The left column lists the big ideas present in the SEP. Some big ideas have clarifying statements underneath them to help the user better understand the SEP. The next 3 columns describe these big ideas in terms of a lesson that is not aligned, partially aligned, and fully aligned.

5) The SEPs tend to favor student directed learning over teacher directed learning. When aligning lessons be sure to recognize who is doing each activity, the student or the teacher.

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
6) Begin with the **fully aligned** column. The number/letter combination in parenthesis corresponds to the attributes listed in the SEP Quick Reference Guide.
   a. Read through what it means for a lesson to be fully aligned.
   b. If the lesson exhibits what is in the fully aligned box it is considered aligned to that SEP.

7) If the lesson does not fit into the **fully aligned** box, move to the partially aligned box.
   a. If a lesson falls into the **partially aligned** box it is not aligned to that SEP.
   b. Each partially aligned box contains recommendations for increasing alignment. These recommendations are usually small shifts that can be made in the lesson.

8) If the lesson does not fit into the **partially aligned** box move to the **not aligned** box.
   a. If the lesson falls into the **not aligned** box then it is not aligned to this SEP.
   b. No recommendations are included. A lesson can be moved to fully aligned, but considerable changes will need to be made.

9) Repeat steps 5-7 for each row of the rubric.

10) Repeat steps 3-7 for each additional rubric.

At least one part of the lesson must fall into a fully aligned box in order to be considered aligned to the SEP.

Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
Science and Engineering Practices (SEP) Quick Reference Guide

This page is intended to be a quick reference sheet used when analyzing a lesson to help eliminate constant flipping between eight different rubrics. It is still necessary to read and answer the questions on the front page of each rubric to determine if the lesson is aligned. Remember: A lesson must also be connected to at least one DCI and/or one CCC to be considered fully aligned to the NGSS.

The attributes are arranged by topic. Some attributes appear in more than one category.

If the lesson contains attributes not contained on this sheet, the lesson may not be aligned or it may be aligned to a different grade band. Please see Appendix F of NGSS for information on different grade bands.

Each fully aligned square of the rubrics has a number and letter designation, for example 3c. These designations are found in the “rubric square” column and are bolded in the rubrics before the text in the “fully aligned” column.

### SEP #1: Asking Questions?

<table>
<thead>
<tr>
<th>Rubric Square</th>
<th>Attribute</th>
<th>Use SEP Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Distinguishing between scientific (testable) and non-scientific (non-testable) questions</td>
<td>#1: Asking Questions and Defining Problems</td>
</tr>
<tr>
<td>1b</td>
<td>Asking questions that can be investigated (tested)</td>
<td>#1: Asking Questions and Defining Problems</td>
</tr>
<tr>
<td>1c</td>
<td>Asking questions about variables</td>
<td>#1: Asking Questions and Defining Problems</td>
</tr>
</tbody>
</table>

### SEP #2: Developing and Using Models?

<table>
<thead>
<tr>
<th>Rubric Square</th>
<th>Attributes</th>
<th>Use SEP Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>Identifying limitations of models</td>
<td>#2: Developing and Using Models</td>
</tr>
<tr>
<td>2b/2c</td>
<td>Developing models, diagrams, or physical prototypes</td>
<td>#2: Developing and Using Models</td>
</tr>
<tr>
<td>2d</td>
<td>Using models to predict phenomena</td>
<td>#2: Developing and Using Models</td>
</tr>
<tr>
<td>2e</td>
<td>Using a model to test relationships or interactions within a system</td>
<td>#2: Developing and Using Models</td>
</tr>
</tbody>
</table>

### SEP #3: Planning or Conducting Investigations?

<table>
<thead>
<tr>
<th>Rubric Square</th>
<th>Attributes</th>
<th>Use SEP Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Asking questions that can be investigated (tested)</td>
<td>#1: Asking questions and defining problems</td>
</tr>
<tr>
<td>2e</td>
<td>Using a model to test relationships or interactions within a system</td>
<td>#2: Developing and Using Models</td>
</tr>
<tr>
<td>3a</td>
<td>Planning and conducting investigations</td>
<td>#3: Planning and Carrying Out Investigations</td>
</tr>
<tr>
<td>3b/3c</td>
<td>Producing and/or collecting data</td>
<td>#3: Planning and Carrying Out Investigations</td>
</tr>
<tr>
<td>3c</td>
<td>Making observations</td>
<td>#3: Planning and Carrying Out Investigations</td>
</tr>
<tr>
<td>3d</td>
<td>Making predictions</td>
<td>#3: Planning and Carrying Out Investigations</td>
</tr>
<tr>
<td>3e</td>
<td>Testing different models of the same object, tool, or process</td>
<td>#3: Planning and Carrying Out Investigations</td>
</tr>
</tbody>
</table>

### SEP #4: Analyzing and Interpreting Data and SEP #5: Mathematics or Computational Thinking?

<table>
<thead>
<tr>
<th>Rubric Square</th>
<th>Attributes</th>
<th>Use SEP Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td>3b/3c</td>
<td>Producing and/or collecting data</td>
<td>#3: Planning and Carrying Out Investigations</td>
</tr>
<tr>
<td>4a</td>
<td>Representing data in tables and/or graphs</td>
<td>#4: Analyzing and Interpreting Data</td>
</tr>
<tr>
<td>4b</td>
<td>Using data to make sense of phenomena</td>
<td>#4: Analyzing and Interpreting Data</td>
</tr>
<tr>
<td>4c</td>
<td>Comparing and contrasting different sets of data</td>
<td>#4: Analyzing and Interpreting Data</td>
</tr>
<tr>
<td>4d</td>
<td>Analyzing data to refine design problems and/or solutions</td>
<td>#4: Analyzing and Interpreting Data</td>
</tr>
<tr>
<td>5a</td>
<td>Deciding on the best type of data to collect when evaluating a design solution</td>
<td>#5: Using Mathematics and Computational Thinking</td>
</tr>
<tr>
<td>5b</td>
<td>Organizing data sets to reveal patterns and relationships</td>
<td>#5: Using Mathematics and Computational Thinking</td>
</tr>
</tbody>
</table>

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
| 5c | Describing, measuring, estimating, and/or graphing quantities | #5: Using Mathematics and Computational Thinking |
| 5d | Creating and/or using graphs generated from simple algorithms (a simple set of instructions for completing a task) | #5: Using Mathematics and Computational Thinking |

### SEP #6: Constructing Explanations?

<table>
<thead>
<tr>
<th>Rubric Square</th>
<th>Attributes</th>
<th>Use SEP Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td>6a</td>
<td>Constructing explanations</td>
<td>#6: Constructing Explanations and Designing Solutions</td>
</tr>
<tr>
<td>6b</td>
<td>Using evidence to construct or support an explanation or design solution</td>
<td>#6: Constructing Explanations and Designing Solutions</td>
</tr>
<tr>
<td>6c</td>
<td>Identifying evidence that supports a particular point in an explanation</td>
<td>#6: Constructing Explanations and Designing Solutions</td>
</tr>
<tr>
<td>7b</td>
<td>Distinguishing between facts, reasoned judgment, and speculation</td>
<td>#7: Engaging in Argument from Evidence</td>
</tr>
</tbody>
</table>

### SEP #7: Engaging in Argumentation?

<table>
<thead>
<tr>
<th>Rubric Square</th>
<th>Attributes</th>
<th>Use SEP Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td>7a/7c</td>
<td>Constructing, comparing, or refining arguments</td>
<td>#7: Engaging in Argument from Evidence</td>
</tr>
<tr>
<td>7b</td>
<td>Distinguishing between facts, reasoned judgment, and speculation</td>
<td>#7: Engaging in Argument from Evidence</td>
</tr>
<tr>
<td>7c/7d/7e</td>
<td>Making or evaluating claims</td>
<td>#7: Engaging in Argument from Evidence</td>
</tr>
<tr>
<td>7f</td>
<td>Providing and receiving critiques</td>
<td>#7: Engaging in Argument from Evidence</td>
</tr>
</tbody>
</table>

### SEP #8: Obtaining and Communicating Information?

<table>
<thead>
<tr>
<th>Rubric Square</th>
<th>Attributes</th>
<th>Use SEP Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td>8a</td>
<td>Reading grade appropriate complex texts and other media</td>
<td>#8: Obtaining, Evaluating, and Communicating Information</td>
</tr>
<tr>
<td>8b</td>
<td>Obtaining and combining information from books and/or other media to explain phenomena or solutions to design problems</td>
<td>#8: Obtaining, Evaluating, and Communicating Information</td>
</tr>
<tr>
<td>8c</td>
<td>Communicating scientific and/or technical information orally and/or in written formats</td>
<td>#8: Obtaining, Evaluating, and Communicating Information</td>
</tr>
<tr>
<td>8d/8e</td>
<td>Combining and/or comparing information in written texts and other media to support engagement in other SEPs</td>
<td>#8: Obtaining, Evaluating, and Communicating Information</td>
</tr>
</tbody>
</table>

### Engineering? (Present in all SEPs)

<table>
<thead>
<tr>
<th>Rubric Square</th>
<th>Attributes</th>
<th>Use SEP Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1d/1e</td>
<td>Describing or defining solvable problems</td>
<td>#1: Asking questions and defining problems</td>
</tr>
<tr>
<td>2b/2c</td>
<td>Developing models, diagrams, or physical prototypes</td>
<td>#2: Developing and Using Models</td>
</tr>
<tr>
<td>3e</td>
<td>Testing different models of the same object, tool, or process</td>
<td>#3: Planning and Carrying Out Investigations</td>
</tr>
<tr>
<td>4d</td>
<td>Analyzing data to refine design problems and/or solutions</td>
<td>#4: Analyzing and Interpreting Data</td>
</tr>
<tr>
<td>5a</td>
<td>Deciding on the best type of data to collect when evaluating a design solution</td>
<td>#5: Using Mathematics &amp; Computational Thinking</td>
</tr>
<tr>
<td>6d</td>
<td>Applying scientific ideas to solve design problems</td>
<td>#6: Constructing Explanations and Designing Solutions</td>
</tr>
<tr>
<td>6e</td>
<td>Generating multiple solutions to a problem</td>
<td>#6: Constructing Explanations and Designing Solutions</td>
</tr>
<tr>
<td>8b</td>
<td>Obtaining and combining information from books and/or other media to explain phenomena or solutions to design problems</td>
<td>#8: Obtaining, Evaluating, and Communicating Information</td>
</tr>
</tbody>
</table>

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
SEP #1: Asking Questions and Defining Problems
Lesson Evaluation Rubric for 3rd-5th Grade

1) Are student-generated questions a part of this lesson?
   OR
   Are students defining problems as a part of this lesson?

   If yes, continue to question 2.
   If no, the SEP “asking questions and defining problems” is not present in this lesson.

2) Does the lesson state that students are doing at least one of the following?
   a. Distinguishing between scientific (testable) and non-scientific (non-testable) questions
   b. Asking questions that can be investigated (tested)
   c. Asking questions about variables
   d. Describing or defining solvable problems

   If yes, continue to question 3.
   If no, the SEP “asking questions and defining problems” is not present in this lesson or it is present at a different grade band. Please see Appendix F of the NGSS for more information on grade band expectations.

3) Does the lesson connect to at least one 3rd-5th grade Disciplinary Core Idea (DCI) and/or one CCC (Crosscutting Concept)?
   For a list of DCIs and CCCs please reference the NGSS available online at www.nextgenscience.org
   If yes, continue to the rubric.
   If no, this lesson is not fully aligned to this SEP. A fully aligned lesson combines content and practice. Connect this lesson to a DCI and/or CCC for full alignment

In addition to answering yes to the first three questions a lesson must fall under “Fully Aligned” in at least one area of the rubric to be considered aligned to the NGSS.

If the lesson does not contain any aspects in the “Fully Aligned” column it is not considered aligned to the NGSS.

Follow the recommendations in the “Partially Aligned” column to help align the lesson. These are often small shifts within the lesson.

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
<table>
<thead>
<tr>
<th>SEP #1: Asking Questions and Defining Problems</th>
<th>Lesson Evaluation Rubric for 3rd-5th Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Questions</td>
<td>Fully Aligned</td>
</tr>
<tr>
<td>Clarification Statement: Scientific questions are questions about phenomena that can be tested, by doing an experiment, to help us develop explanations for the phenomena. Testable questions are not opinion based (e.g., Which flower is the prettiest? Is not a scientific testable question)</td>
<td>In the lesson the teacher is identifying scientific (testable) and non-scientific (non-testable) questions for students. This could include students asking questions and the teacher classifying them. <strong>Recommendation:</strong> Alter the lesson so that students are classifying questions as scientific or non-scientific. <strong>OR</strong> The lesson does not explicitly state that students will identify scientific (testable) and non-scientific (non-testable) questions, but doing so is imperative to completing the lesson. <strong>Recommendation:</strong> Make this concept explicit by writing it into the lesson.</td>
</tr>
<tr>
<td>(1a) The lesson explicitly states that <strong>students</strong> will identify scientific (testable) and non-scientific (non-testable) questions.</td>
<td><strong>Recommendation:</strong> When the question is teacher generated students are not doing this aspect of the SEP, allow time in the lesson for students to come up with their own questions and predictions about phenomena. <strong>OR</strong> In the lesson <strong>students</strong> are asking questions that can be investigated (tested), but they are not predicting reasonable outcomes for their questions. <strong>Recommendation:</strong> Expand the lesson so that students are predicting reasonable outcomes based on patterns for their questions.</td>
</tr>
<tr>
<td>(1b) The lesson explicitly states that <strong>students</strong> will be asking questions that can be investigated (tested). <strong>Students</strong> will also predict reasonable outcomes for those questions based on patterns. (i.e., Cause and effect relationships, What happens to a plant when it kept in the dark? Prediction: I think the plant will die.)</td>
<td>In the lesson <strong>students are not given the opportunity</strong> to ask questions that can be investigated (tested), but are asked to predict reasonable outcomes (based on patterns) from a teacher-generated question. <strong>Recommendation:</strong> When the question is teacher generated students are not doing this aspect of the SEP, allow time in the lesson for students to come up with their own questions and predictions about phenomena. <strong>OR</strong> In the lesson <strong>students</strong> are asking questions that can be investigated (tested), but they are not predicting reasonable outcomes for their questions. <strong>Recommendation:</strong> Expand the lesson so that students are predicting reasonable outcomes based on patterns for their questions.</td>
</tr>
<tr>
<td>Changing Variables</td>
<td>(1c) The lesson explicitly states that <strong>students</strong> have the opportunity to and will ask questions about what would happen if a variable is changed.</td>
</tr>
</tbody>
</table>

Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
### SEP #1: Asking Questions and Defining Problems Rubric (continued)

<table>
<thead>
<tr>
<th>Solvable Problems</th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clarification Statement:</strong></td>
<td>The lesson explicitly states that students will use prior knowledge to clearly describe problems that can be solved in terms of criteria for success and any constraints or limitations they may have.</td>
<td>In the lesson the teacher is describing problems that can be solved in terms of criteria for success and constraints. <strong>Recommendations:</strong> Have students describe the problem, not the teacher.</td>
<td>In the lesson students are not asked to use prior knowledge to describe problems that can be solved.</td>
</tr>
<tr>
<td>Example: Mr. Smith’s class notices that after recess the classroom floor is often very wet and several students slip and fall. In order to solve this problem they determine that the ground must stay dry even after wet shoes have walked on it. They know that they are limited by time (they only have 30 minutes in class to find a solution) and materials/cost (Mr. Smith gave them a budget of $10 and let them use anything they could find in the room).</td>
<td>The lesson does not explicitly state that students will be using prior knowledge to describe problems, but doing so is imperative to the completion of the lesson and/or implied in the instructions. <strong>Recommendations:</strong> Make this concept explicit by writing it into the lesson being sure to include what constitutes a full description of the problem.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Criteria for success—what is required for the solution to be successful.</strong></td>
<td>In the lesson the teacher is defining a simple design problem and students are solving it through the development of an object, tool, process, or system. <strong>Recommendation:</strong> Alter the lesson so students are defining the design problem.</td>
<td>In the lesson students are not required to define a simple design problem that can be solved.</td>
<td></td>
</tr>
<tr>
<td><strong>Constraints—things that limit a solution such as time, materials, or cost.</strong></td>
<td><strong>Recommendations:</strong> Take the current design problem deeper by adding in the piece(s) that are missing, make it solvable, include criteria for success, and contain constraints on materials, time, or cost.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
SEP #2: Developing and Using Models
Lesson Evaluation Rubric for 3rd-5th Grade

Models include diagrams, physical replicas, mathematical representations, analogies, and computer simulations.

1) Is creating or using models a part of this lesson?
   If yes, continue to question 2.
   If no, the SEP “Developing and Using Models” is not part of this lesson.

2) Does the lesson state that students will be doing at least one of the following?
   a. Identifying limitations of models
   b. Developing models, diagrams, or physical prototypes
   c. Using models to predict phenomena
   d. Using a model to test relationships or interactions within a system
   If at least one of the above is stated, continue to question 3.
   If no, the SEP “Developing and Using Models” is not present in this lesson or it is present at a different grade band. Please see Appendix F of the NGSS for more information on grade band expectations.

3) Does the lesson connect to at least one 3rd-5th grade Disciplinary Core Idea (DCI) and/or one CCC (Crosscutting Concept)?
   For a list of DCIs and CCCs please reference the NGSS available online at www.nextgenscience.org
   If yes, continue to the rubric.
   If no, this lesson is not fully aligned to this SEP. A fully aligned lesson combines content and practice. Connect this lesson to a DCI and/or CCC for full alignment

In addition to answering yes to the first three questions a lesson must fall under “Fully Aligned” in at least one area of the rubric to be considered aligned to the NGSS.

If the lesson does not contain any aspects in the “Fully Aligned” column it is not considered aligned to the NGSS.

Follow the recommendations in the “Partially Aligned” column to help align the lesson. These are often small shifts within the lesson.

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
## SEP #2: Developing and Using Models
### Lesson Evaluation Rubric for 3rd - 5th Grade

### Limitations

**Clarification Statement:**
Models do not correspond exactly to the real world. All models contain approximations and assumptions that limit the range of validity and predictive power so it is important for students to recognize their limitations (NGSS Appendix F).

- **Fully Aligned**
  - (2a) The lesson explicitly states that students will identify limitations of models.

- **Partially Aligned**
  - In the lesson the teacher is identifying limitations of models for students.
  - **Recommendation:** Alter the lesson so that students are identifying the limitations of models, not teachers.
  - OR
  - The lesson does not explicitly state that students will identify limitations of models, but doing so is imperative to completing the lesson.
  - **Recommendation:** Make this concept explicit by writing it into the lesson.

- **Not Aligned**
  - The lesson does not include students identifying limitations of models.

### Developing Models

**Clarification Statement:**
Students are developing models, not teachers. This is an important distinction for this SEP. Models provided by the teacher are valuable learning tools, but they do not exemplify this practice.

- **Fully Aligned**
  - (2b) The lesson explicitly states that students will work collaboratively to develop and/or revise a model based on evidence (i.e., prior knowledge/experiences, research, investigations) that shows the relationships among variables for frequent and regular occurring events (i.e. the water cycle, moon phases).

- **Partially Aligned**
  - In the lesson the teacher is developing and/or revising a model that shows relationships among variables for frequent and regular occurring events, the students are using the teacher-developed model.
  - **Recommendations:** Allow students to collaboratively develop and/or revise a model.
  - OR
  - In the lesson students are not given the opportunity to work collaboratively when developing and/or revising a model.
  - **Recommendation:** Adjust the lesson to involve students working together when developing and/or revising models.

- **Not Aligned**
  - In the lesson students are not given the opportunity to work collaboratively to develop and/or revise a model.

- **Fully Aligned**
  - (2c) The lesson explicitly states that students will develop a diagram (drawing) or simple physical prototype to express their ideas for a proposed object, tool, or process.

- **Partially Aligned**
  - In the lesson the teacher develops a diagram (drawing) or simple physical prototype for a proposed object, tool, or process and the students use it for the duration of the lesson, never creating their own models.
  - **Recommendation:** Allow students to develop the diagram (drawing) or simple physical prototype of their own ideas.
  - OR
  - In the lesson students may be asked to develop a diagram (drawing) or simple physical prototype, but not of their own ideas. This could include copying a diagram from a book or other source, or creating a physical prototype following a

- **Not Aligned**
  - In the lesson students are not asked to develop a diagram (drawing) or simple physical prototype to express their ideas for a proposed object, tool, or process.

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Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
SEP #2: Developing and Using Models Rubric (continued)

<table>
<thead>
<tr>
<th>Specific set of instructions. <strong>Recommendation:</strong> Do not provide students with something to copy. Allow them to use their creativity and their own ideas when developing the diagram or physical prototype.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(2d)</strong> The lesson explicitly states that students will develop a model using an analogy, example, or abstract representation to describe and/or predict phenomena. (i.e. A drawing of evaporation or a representation of how humans smell odors)</td>
</tr>
<tr>
<td>In the lesson students are not given the opportunity to develop a model. The <strong>teacher provides the model</strong> and students use it to describe and/or predict phenomena. <strong>Recommendation:</strong> Build time into the lesson for students to develop their own models. A teacher provided model is a first step in scaffolding students towards developing their own models, but does not align with this SEP.</td>
</tr>
<tr>
<td>In the lesson students will have no opportunity to develop a model using an analogy, example, or abstract representation to describe and/or predict phenomena</td>
</tr>
</tbody>
</table>
### SEP #3: Planning and Carrying Out Investigations

#### Lesson Evaluation Rubric for 3rd-5th Grade

1) Does the lesson involve planning and/or carrying out investigations?
   - If yes, continue to question 2.
   - If no, the SEP “Planning and Carrying Out Investigations” is not part of this lesson

2) Does the lesson state that students will be doing at least one of the following?
   - a. Planning and conducting investigations
   - b. Producing and/or collecting data
   - c. Making predictions
   - d. Testing different models of the same object, tool, or process

   - If at least one of the above is stated, continue to question 3.
   - If no, the SEP “Planning and Carrying Out Investigations” is not present in this lesson or it is present at a different grade band. Please see Appendix F of the NGSS for more information on grade band expectations.

3) Does the lesson connect to at least one 3rd-5th grade Disciplinary Core Idea (DCI) and/or one CCC (Crosscutting Concept)?
   - For a list of DCIs and CCCs please reference the NGSS available online at [www.nextgenscience.org](http://www.nextgenscience.org)
   - If yes, continue to the rubric.
   - If no, this lesson is not fully aligned to this SEP. A fully aligned lesson combines content and practice. Connect this lesson to a DCI and/or CCC for full alignment

In addition to answering yes to the first three questions a lesson must fall under “Fully Aligned” in at least one area of the rubric to be considered aligned to the NGSS.

If the lesson does not contain any aspects in the “Fully Aligned” column it is not considered aligned to the NGSS.

Follow the recommendations in the “Partially Aligned” column to help align the lesson. These are often small shifts within the lesson.

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Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
| SEP #3: Planning and Carrying Out Investigations | Planning and Conducting Investigations | Data

Clarification Statement:
Data can be collected in the qualitative (notes or observations) or quantitative (measurements) form. Students must decide what measurements should be taken, how accurate the measurements need to be, and what tools will take the best measurements. At this level students will use data as evidence to explain a phenomena or evaluate a design solution.

(3a) The lesson explicitly states that students will collaboratively plan and conduct an investigation. The criteria for the investigation must also be listed in the lesson. This includes all of the following, Students will be asked to:

1) Produce data (qualitative or quantitative) and,
2) Use fair tests (controlling for variables so that only one variable is being tested at a time) and,
3) Consider the number of trials performed

The lesson may explicitly state that students are carrying out an investigation, but not one that they have planned. This includes teacher-designed investigations done by students.

**Recommendation:** Present students with the same basis for the investigation but allow them to work together to come up with their own plan for an investigation.

OR

The lesson does not give the students an opportunity to plan the investigation collaboratively.

**Recommendation:** Allow students to work as a class or in small groups to plan the investigation.

OR

The lesson does explicitly state that students will plan and conduct an investigation, but it does not contain all of the criteria students must include in their investigation. The teacher may urge students to include these items when doing the lesson but they are not written into the lesson. This includes all of the following, Students will be asked to:

1) Produce data (qualitative or quantitative)
2) Use fair tests (controlling for variables so that only one variable is being tested at a time)
3) Consider the number of trials performed

**Recommendation:** Make this part of the lesson explicit by writing in any missing criteria for planning the investigation.

(3b) The lesson explicitly states that when planning an investigation students will be given the opportunity to consider different methods and tools needed for collecting data (i.e. when measuring how far a ball rolls after traveling down a ramp students must decide how to measure the distance, inches, cm, ft or m, and what tool will give the most accuracy, a tape measure, 12 in ruler, or meter stick)

The lesson explicitly states that when planning an investigation students will be collecting data, but they will not plan what data to collect or what tools will be used to collect it. The teacher decides what data will be collected and how to collect it.

**Recommendation:** Build time into the lesson for students to decide what data they need to collect and how they will collect it.

The lesson does not give students the opportunity to plan and carry out an investigation.

In the lesson, when planning an investigation students do not have the opportunity to consider different methods and/or tools for collecting data.

<table>
<thead>
<tr>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
</table>
| (3a) The lesson explicitly states that students will collaboratively plan and conduct an investigation. The criteria for the investigation must also be listed in the lesson. This includes all of the following, Students will be asked to:
1) Produce data (qualitative or quantitative) and,
2) Use fair tests (controlling for variables so that only one variable is being tested at a time) and,
3) Consider the number of trials performed |

**Recommendation:** Present students with the same basis for the investigation but allow them to work together to come up with their own plan for an investigation.

OR

The lesson does not give the students an opportunity to plan the investigation collaboratively.

**Recommendation:** Allow students to work as a class or in small groups to plan the investigation.

OR

The lesson does explicitly state that students will plan and conduct an investigation, but it does not contain all of the criteria students must include in their investigation. The teacher may urge students to include these items when doing the lesson but they are not written into the lesson. This includes all of the following, Students will be asked to:

1) Produce data (qualitative or quantitative)
2) Use fair tests (controlling for variables so that only one variable is being tested at a time)
3) Consider the number of trials performed

**Recommendation:** Make this part of the lesson explicit by writing in any missing criteria for planning the investigation. |

<table>
<thead>
<tr>
<th>Data</th>
</tr>
</thead>
</table>

**Clarification Statement:**
Data can be collected in the qualitative (notes or observations) or quantitative (measurements) form. Students must decide what measurements should be taken, how accurate the measurements need to be, and what tools will take the best measurements. At this level students will use data as evidence to explain a phenomena or evaluate a design solution. |
### Data (continued)

| (3e) The lesson explicitly states that students will collect data by making observations (qualitative data) and/or measurements (quantitative data). The data collected will then serve as the basis for evidence in an explanation of a phenomena or when testing a possible design solution. | In the lesson students are collecting data by making observations (qualitative data) and/or measurements (quantitative data) but that data is not used as evidence for explaining a phenomena or when testing a possible design solution. **Recommendation:** Do not stop at data collection, have students use their data when explaining what happened in the investigation or when testing design solutions. Data does not become evidence until it is used when supporting a claim. **Recommendation:** Alter the lesson so that students have the opportunity to collect the data they are using for evidence. | In the lesson students are not collecting data by making observations (qualitative data) or by taking measurements (quantitative data). |

### Predictions

**Clarification Statement:**
A prediction is not the same as a hypothesis. A prediction is a proposed explanation for phenomena, not necessarily tested. A true hypothesis requires actually testing the proposed explanation. In this SEP students are only required to predict, they do not necessarily have to test their predictions.

| (3d) The lesson explicitly states that students will make predictions about what would happen if a variable changes. Students can, but do not need to test these predictions. | The lesson states that students will be making predictions about the investigation, but not about what would happen if a variable changes. **Recommendation:** Add time into the lesson for students to make predictions about what would happen if different variables were changed. These predictions do not have to be tested. | In the lesson students are not making predictions about what would happen if a variable changes. |

### Developing Solutions

**Clarification Statement:**
In this phase of engineering design students research and explore multiple solutions to a problem in order to determine which design best meets their criteria for success (what it means for the product to be successful).

| (3e) The lesson explicitly states that students will test two different models of the same proposed object, tool, or process then determine which best meets their criteria for success. | In this lesson students test two different models of the same proposed object, tool, or process but do not evaluate them to determine which best met their criteria for success. This could include the teacher determining which object, tool, or process best meets the criteria for success. **Recommendation:** Add to the lesson time for students to determine which object, tool, or process best meets the criteria for success based on test results **OR** In this lesson students only test one model of a proposed object, tool, or process and determine how well it meets the criteria for success. **Recommendation:** Add to the lesson the development and testing of a second proposed object, tool, or process. Then, include time for students to determine which best meets the criteria for success. | In the lesson students do not test two different models of the same proposed object, tool, or process to determine which best meets the criteria for success. |

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Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
SEP #4: Analyzing and Interpreting Data
Lesson Evaluation Rubric for 3rd-5th Grade

1) Does the lesson involve analyzing or interpreting data?
   If yes, continue to question 2.
   If no, the SEP “Analyzing and Interpreting Data” is not part of this lesson

2) Does the lesson state that students will be doing at least one of the following?
   a. Representing data in tables and/or graphs
   b. Using data to make sense of phenomena
   c. Comparing and contrasting different sets of data
   d. Analyzing data to refine design problems and/or solutions

   If at least one of the above is stated, continue to question 3.
   If no, the SEP “Analyzing and Interpreting Data” is not present in this lesson or it is present at a different grade band. Please see Appendix F of the NGSS for more information on grade band expectations.

3) Does the lesson connect to at least one 3rd-5th grade Disciplinary Core Idea (DCI) and/or one CCC (Crosscutting Concept)?
   For a list of DCIs and CCCs please reference the NGSS available online at www.nextgenscience.org
   If yes, continue to the rubric.
   If no, this lesson is not fully aligned to this SEP. A fully aligned lesson combines content and practice. Connect this lesson to a DCI and/or CCC for full alignment

In addition to answering yes to the first three questions a lesson must fall under “Fully Aligned” in at least one area of the rubric to be considered aligned to the NGSS.

If the lesson does not contain any aspects in the “Fully Aligned” column it is not considered aligned to the NGSS.

Follow the recommendations in the “Partially Aligned” column to help align the lesson. These are often small shifts within the lesson.

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
SEP #4: Analyzing and Interpreting Data
Lesson Evaluation Rubric for 3rd-5th Grade

<table>
<thead>
<tr>
<th>Representing Data</th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clarification Statement:</strong> Data can be… qualitative (observations) or quantitative (measurements).</td>
<td>(4a) The lesson explicitly states that students will represent data in tables and/or graphs (bar graphs, pictographs, and/or pie charts). Students will be asked to use the charts and/or graphs to find patterns that indicate relationships. <em>Data can be collected by students or provided by the teacher for students to analyze.</em></td>
<td>In the lesson students are representing data in tables and/or graphs (bar graphs, pictographs, and/or pie graphs) but are not asked to interpret them by finding patterns that indicate relationships. This includes the teacher finding patterns and indicating relationships for students. <em>Data can be collected by students or provided by the teacher for students to analyze.</em> <strong>Recommendation:</strong> Add to the lesson the opportunity for students to interpret the graphs they have created. <strong>OR</strong> In the lesson the teacher will represent data in tables and/or graphs (bar graphs, pictographs, and/or pie charts). Students will be asked to use the charts and/or graphs to find patterns that indicate relationships. <em>Data can be collected by students or provided by the teacher for students to analyze.</em> <strong>Recommendation:</strong> Add to the lesson the opportunity for students to represent data in tables and/or graphs.</td>
<td>The lesson does not give students the opportunity to represent data in tables and/or graphical displays.</td>
</tr>
</tbody>
</table>

| Understanding Phenomena | (4b) The lesson explicitly states that students will examine and interpret data using logical reasoning, mathematics, and/or computational thinking to help them understand phenomena. *Data can be collected by students or provided by the teacher for students to analyze.* | The lesson states that students will examine and/or interpret data but does not indicate that students will use their analysis when trying to understand a phenomena. *Data can be collected by students or provided by the teacher for students to analyze.* **Recommendation:** Explicitly state in the lesson that students will use data to help them understand a phenomena. | In the lesson students are not given the opportunity to examine or interpret data. |

| Similarities and Differences in Data | (4c) The lesson explicitly states that students will examine data collected by at least 2 different groups. Students will compare and contrast the data sets then discuss the similarities and differences in their findings. *Data can be collected by students or provided by the teacher for students to analyze.* | The lesson states that students will examine data collected by at least 2 different groups. However, students are not comparing and contrasting the data sets and/or participating in a discussion surrounding their similarities and differences. *Data can be collected by students or provided by the teacher for students to analyze.* **Recommendation:** Specify that in their data analysis students will be comparing and contrasting data from different groups then discussing the similarities and differences. | In the lesson students are not examining data collected by at least 2 different groups. |

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
### SEP #4: Analyzing and Interpreting Data Rubric (continued)

<table>
<thead>
<tr>
<th>Using Data in Engineering</th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td>(4d) The lesson explicitly states that students will use data to improve a problem statement or the design of a proposed object, tool, or process. Data can be collected by students or provided by the teacher for students to analyze.</td>
<td>The lesson states that students will have the opportunity to improve a problem statement (this includes the problem, the criteria for successful solving of the problem, and any constraints or limitations) or the design of a proposed object, tool, or process, but the improvement is not based on data. <strong>Recommendation:</strong> Make it explicit within the lesson that the improvements made to problem statement or design solution will be based off of data. Data can be collected by students or provided by the teacher for students to analyze.</td>
<td>In the lesson students do not use data to improve a problem statement or the design of a proposed object, tool, or process.</td>
<td></td>
</tr>
<tr>
<td>(4e) The lesson explicitly states that students will use data to evaluate and improve design solutions. Data can be collected by students or provided by the teacher for students to analyze.</td>
<td>The lesson states that students will evaluate and improve design solutions, but the improvements are not data-based. <strong>Recommendation:</strong> Include in the lesson that the improvements in the design solution will be based off of data. Data can be collected by students or provided by the teacher for students to analyze.</td>
<td>In the lesson students do not use data to evaluate and/or improve design solutions.</td>
<td></td>
</tr>
</tbody>
</table>

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
| SEP #5: Using Mathematical and Computational Thinking |
| Lesson Evaluation Rubric for 3<sup>rd</sup>–5<sup>th</sup> Grade |

1) Does the lesson involve students using mathematics or computational thinking?

   If yes, continue to question 2.
   If no, the SEP “Using Mathematical and Computational Thinking” is not part of this lesson.

2) Does the lesson state that students will be doing at least one of the following?

   a. Deciding on the best type of data to collect when evaluating a design solution
   b. Organizing data sets to reveal patterns and relationships
   c. Describing, measuring, estimating, and/or graphing quantities
   d. Creating and/or using graphs generated from simple algorithms (a simple set of instructions for completing a task)

   If at least one of the above is stated, continue to rubric.
   If no, the SEP “Using Mathematical and Computational Thinking” is not present in this lesson or it is present at a different grade band.
   Please see Appendix F of the NGSS for more information on grade band expectations.

3) Does the lesson connect to at least one 3<sup>rd</sup>–5<sup>th</sup> grade Disciplinary Core Idea (DCI) and/or one CCC (Crosscutting Concept)?

   For a list of DCIs and CCCs please reference the NGSS available online at [www.nextgenscience.org](http://www.nextgenscience.org).
   If yes, continue to the rubric.
   If no, this lesson is not fully aligned to this SEP. A fully aligned lesson combines content and practice. Connect this lesson to a DCI and/or CCC for full alignment.

In addition to answering yes to the first three questions a lesson must fall under “Fully Aligned” in at least one area of the rubric to be considered aligned to the NGSS.

If the lesson does not contain any aspects in the “Fully Aligned” column it is not considered aligned to the NGSS.

Follow the recommendations in the “Partially Aligned” column to help align the lesson. These are often small shifts within the lesson.

Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
### SEP #5: Using Mathematical and Computational Thinking
Lesson Evaluation Rubric for 3rd-5th Grade

<table>
<thead>
<tr>
<th>Choosing Data Types</th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clarification Statements:</strong></td>
<td>(5a) The lesson explicitly states that students will decide if qualitative or quantitative data are best when determining whether a proposed object or tool meets the criteria for success.</td>
<td>The lesson states that students will use data to determine whether a proposed object or tool meets the criteria for success, but does not give students the opportunity to decide what type of data they will use. Data type has been decided by the teacher. <strong>Recommendation:</strong> Add time into the lesson for students to decide on the best type of data to use to determine the success of a proposed object or tool.</td>
<td>The lesson does not give students the opportunity to decide which type of data is best when determining whether a proposed object or tool meets the criteria for success.</td>
</tr>
<tr>
<td></td>
<td><strong>Organizing Data</strong></td>
<td>(5b) The lesson explicitly states that students will organize simple data sets to reveal patterns that suggest relationships. To see patterns data could be organized into tables and/or graphs (bar graphs, pictographs, and/or pie charts). Data can be collected by students or provided by the teacher for students to analyze.</td>
<td>In the lesson students are organizing simple data sets in tables and/or graphs (bar graphs, pictographs, and/or pie graphs) but are not asked to interpret them by finding patterns that indicate relationships. This includes the teacher finding and showing patterns to students. Data can be collected by students or provided by the teacher for students to analyze. <strong>Recommendation:</strong> Alter the lesson to give students the opportunity to interpret the graphs they have created. OR In the lesson the teacher is organizing simple data sets in tables and/or graphs (bar graphs, pictographs, and/or pie graphs) and students are asked to interpret them by finding patterns that indicate relationships. Data can be collected by students or provided by the teacher for students to analyze. <strong>Recommendation:</strong> Alter the lesson to give students the opportunity to organize simple data sets and to interpret them.</td>
</tr>
<tr>
<td></td>
<td><strong>Using Quantities to Address Questions and Problems</strong></td>
<td>(5c) The lesson explicitly states that students will describe, measure, estimate, and/or graph quantities (e.g., area, volume, time, weight) to help answer scientific questions and solve engineering problems.</td>
<td>The lesson states that students will answer scientific questions and/or solve engineering problems, but does not specify how they will do so. When doing the lesson students may inherently describe, measure, estimate, and/or graph, but it is not written into the lesson. <strong>Recommendation:</strong> Make this aspect explicit in the lesson by specifying the actions students may participate in answering questions or solving problems. OR In the lesson the teacher is describing, measuring, estimating, and/or graphing quantities for students to use when answering scientific questions or solving engineering problems. <strong>Recommendation:</strong> Alter the lesson so that students are describing, measuring, estimating and/or graphing quantities to help them answer scientific questions and solve engineering problems.</td>
</tr>
</tbody>
</table>

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
### SEP #5: Using Mathematical and Computational Thinking Rubric (continued)

<table>
<thead>
<tr>
<th></th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Graphs and Charts from Simple Algorithms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Clarification Statements:</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An algorithm is a process or set of rules to be followed in calculations or other problem solving operations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In this SEP, creating a chart or graph from a simple algorithm means that all students will use a defined process or set of steps to make a chart or graph based on data from a tested solution to a problem. Since all graphs and/or charts are made by the same process it allows students to compare different solutions more easily.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>(5d)</strong> The lesson explicitly states that students will compare alternative solutions to an engineering problem by using and/or creating graphs and/or charts produced from simple algorithms.</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

The lesson states that students will compare alternative solutions to an engineering problem by using and/or creating graphs and/or charts, but does not specify how they will do so. A simple algorithm may be used but is not explicitly named in the lesson. **Recommendation:** Specify how students will compare solutions, be sure the comparison is based on the use or creation of charts and/or graphs produced from a simple algorithm.

OR

The teacher compares alternative solutions to an engineering problem by using and/or creating graphs and/or charts for students. A simple algorithm may be used but is not explicitly named in the lesson. **Recommendation:** Allow students to compare solutions by using a simple algorithm to create charts and/or graphs.

In the lesson students will not compare alternative solutions to an engineering problem.

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Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
**SEP #6: Constructing Explanations and Designing Solutions**  
**Lesson Evaluation Rubric for 3rd-5th Grade**

1) Does the lesson involve students constructing explanations or designing solutions?
   - If yes, continue to question 2.
   - If no, the SEP “Constructing Explanations and Designing Solutions” is not part of this lesson

2) Does the lesson state that students will be doing at least one of the following?
   - a. Constructing explanations
   - b. Using evidence to construct or support an explanation or design solution
   - c. Identifying evidence that supports a particular point in an explanation
   - d. Applying scientific ideas to solve design problems
   - e. Generating multiple solutions to a problem
   
   - If at least one of the above is stated, continue to rubric.
   - If no, the SEP “Constructing Explanations and Designing Solutions” is not present in this lesson or it is present at a different grade band.
     
     Please see Appendix F of the NGSS for more information on grade band expectations.

3) Does the lesson connect to at least one 3rd-5th grade Disciplinary Core Idea (DCI) and/or one CCC (Crosscutting Concept)?
   
   For a list of DCIs and CCCs please reference the NGSS available online at [www.nextgenscience.org](http://www.nextgenscience.org)
   
   - If yes, continue to the rubric.
   - If no, this lesson is not fully aligned to this SEP. A fully aligned lesson combines content and practice. Connect this lesson to a DCI and/or CCC for full alignment

In addition to answering yes to the first three questions a lesson must fall under “Fully Aligned” in at least one area of the rubric to be considered aligned to the NGSS.

If the lesson does not contain any aspects in the “Fully Aligned” column it is not considered aligned to the NGSS.

Follow the recommendations in the “Partially Aligned” column to help align the lesson. These are often small shifts within the lesson.

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Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
### SEP #6: Constructing Explanations and Designing Solutions

#### Lesson Evaluation Rubric for 3rd-5th Grade

<table>
<thead>
<tr>
<th>Constructing Explanations</th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clarification Statement:</strong> In this SEP an explanation links a scientific theory with scientific observations or phenomena, it is a causal explanation that identifies the underlying chain of cause and effect (NRC, 2012; Reiser, Berland, &amp; Kenyon, 2012).</td>
<td>(6a) The lesson explicitly states that students will construct an explanation of a phenomena based on observed relationships. (i.e. constructing an explanation for the distribution of plants in a backyard)</td>
<td>The teacher provides an explanation of phenomena for students based on observed relationships. <strong>Recommendation:</strong> Allow students to come up with their own explanations. <strong>OR</strong> The lesson states that students will construct an explanation but it is not based on observations or the basis for the explanation is not explicitly written in the lesson. <strong>Recommendation:</strong> Make it explicit by adding to the lesson the basis for the explanation (observed relationships).</td>
<td>The lesson does not give students the opportunity to construct an explanation.</td>
</tr>
</tbody>
</table>

#### Using Evidence

| (6b) The lesson explicitly states that students will construct or support an explanation or design a solution to a problem by using evidence (i.e., measurements, observations, patterns). | In the lesson students are constructing or supporting explanations or designing a solution to a problem but not using evidence (e.g., measurements, observations, patterns) or the use of evidence is implied, not explicitly stated. **Recommendation:** Make this explicit by specifying the use of evidence when constructing or supporting explanations or when designing a solution. | In the lesson students are not constructing or supporting an explanation OR they are not designing a solution to a problem. |

| (6c) The lesson explicitly states that students will be presented with an explanation and asked to identify the evidence that supports specific points within it. | In the lesson the teacher identifies evidence that supports specific points of an explanation for students. **Recommendation:** Allow students to identify the evidence. **OR** In the lesson students are presented with an explanation but are not explicitly asked to identify the evidence that supports specific points. This may be implied and/or imperative to the completion of the lesson, but not stated. **Recommendation:** Make this explicit by adding to the lesson that students are identifying supporting evidence for specific points in the explanation. | In the lesson students are presented with an explanation but they are not asked to identify the evidence that supports it. |

#### Solving Design Problems

| **Clarification Statements:** Criteria-what is required for the solution to be successful. Constraints-things that limit a solution such as time, materials, or cost. | (6d) The lesson explicitly states that students will use their knowledge of science to solve design problems. | In the lesson students are using their knowledge of science to solve design problems, but it is not explicitly stated in the lesson. **Recommendation:** Make the use of scientific knowledge explicit in the lesson. | In the lesson students are not solving design problems. |

| (6e) The lesson explicitly states that students will come up with multiple solutions to a problem. They will also compare these solutions based on how well they meet the established criteria and constraints of the problem. | In the lesson students will come up with multiple solutions to a problem, but will not compare solutions based on how well they meet the criteria and constraints of the design problem. **Recommendation:** Make comparing solutions based on how well they meet the established criteria and constraints of the design problem a part of the lesson. **OR** In the lesson students evaluate a single solution on how well it meets criteria and constraints. **Recommendation:** Have students generate more than one solution. Instead of evaluating a single solution, evaluate multiple. | In the lesson students will come up with only one solution to a problem. |

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Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
SEP #7: Engaging in Argument From Evidence
Lesson Evaluation Rubric for 3rd-5th Grade

1) Does the lesson involve students participating in argumentation?
   
   If yes, continue to question 2.
   If no, the SEP “Engaging in Argument From Evidence” is not part of this lesson.

2) Does the lesson state that students will be doing at least one of the following?
   a. Constructing, comparing, or refining arguments
   b. Distinguishing between facts, reasoned judgment, and speculation
   c. Providing and receiving critiques
   d. Making or evaluating claims

   If at least one of the above is stated, continue to rubric.
   If no, the SEP “Engaging in Argument From Evidence” is not present in this lesson or it is present at a different grade band. Please see Appendix F of the NGSS for more information on grade band expectations.

3) Does the lesson connect to at least one 3rd-5th grade Disciplinary Core Idea (DCI) and/or one CCC (Crosscutting Concept)? For a list of DCIs and CCCs please reference the NGSS available online at www.nextgenscience.org
   If yes, continue to the rubric.
   If no, this lesson is not fully aligned to this SEP. A fully aligned lesson combines content and practice. Connect this lesson to a DCI and/or CCC for full alignment

In addition to answering yes to the first three questions a lesson must fall under “Fully Aligned” in at least one area of the rubric to be considered aligned to the NGSS.

If the lesson does not contain any aspects in the “Fully Aligned” column it is not considered aligned to the NGSS.

Follow the recommendations in the “Partially Aligned” column to help align the lesson. These are often small shifts within the lesson.

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
### SEP #7: Engaging in Argument From Evidence

**Lesson Evaluation Rubric for 3rd-5th Grade**

<table>
<thead>
<tr>
<th><strong>Constructing Arguments</strong></th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clarification Statements:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argument- a claim based on evidence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evidence- not opinion based, something that gives a sign or proof of the existence or truth of something, or that helps somebody to come to a particular conclusion, this could include observations, measurements, or patterns. Data- could include qualitative (notes or observations) or quantitative (measurements) data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model- representations of phenomena that allow us to better understand them; can include drawings, diagrams, mathematical models, graphs, charts, physical representations, and simulations. (NRC, 2012)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7a) The lesson explicitly states that students will construct and/or support an argument with evidence, data, and/or a model.</td>
<td>The lesson states that students will construct and/or support an argument, but the use of evidence, data, and/or a model is not specified. <strong>Recommendation:</strong> Make the lesson explicit by specifying that students will construct and/or support an argument by using evidence, data, and/or a model.</td>
<td>The lesson does not give students the opportunity to construct and/or support an argument.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Analyzing Explanations</strong></th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clarification Statements:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facts-Something that truly exists or happens</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speculation-Reasoning based on incomplete facts or information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7b) The lesson explicitly states that when presented with an explanation students will determine which parts or it are facts, reasoned judgments based on research findings, and speculation.</td>
<td>The lesson does not explicitly state that students will be determining which parts of an explanation are facts, reasoned judgments based on research findings, and speculation, but doing so is imperative to the lesson. <strong>Recommendation:</strong> Make this explicit by stating in the lesson that students will be distinguishing between the three. <strong>OR</strong> In the lesson the teacher is determining which parts of an explanation are facts, reasoned judgment based on research findings, and speculation then presenting that information to students. <strong>Recommendation:</strong> Shift this part of the lesson to the students; ask them to distinguish between the three.</td>
<td>In the lesson students are not asked to distinguish among facts, reasoned judgment based on research findings, and speculation.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Using Evidence</strong></th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td>(7c) The lesson explicitly states that students will compare and improve arguments based on an evaluation of the evidence presented.</td>
<td>The lesson states that students will compare OR improve arguments. <strong>Recommendation:</strong> Add to the lesson that students will compare AND improve their arguments. <strong>OR</strong> The lesson states that students will compare and/or improve arguments, but not based on an evaluation of evidence. <strong>Recommendation:</strong> Include in the lesson that students must base their comparisons and improvements of arguments on evidence.</td>
<td>In the lesson students are not asked to compare and/or improve arguments.</td>
<td></td>
</tr>
</tbody>
</table>

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
### SEP #7: Engaging in Argument from Evidence Rubric (continued)

<table>
<thead>
<tr>
<th>Using Evidence (continued)</th>
</tr>
</thead>
</table>
| **(7d)** The lesson explicitly states that **students** will use data to evaluate claims made about cause and effect. | In the lesson the **teacher** uses data to evaluate students’ claims about cause and effect.  
**Recommendation:** Allow students to evaluate claims on their own.  
OR  
The lesson states that **students** will evaluate claims, but not explicitly claims made about cause and effect.  
**Recommendation:** Make this explicit by adding to the lesson that the evaluation will be of claims specific to cause and effect.  
OR  
The lesson states that **students** will evaluate claims made about cause and effect, but does not specify they will use data to do so.  
**Recommendation:** Make this explicit by adding to the lesson that the evaluation of claims will be done based on data. | In the lesson students are not asked to use data to evaluate claims. |

<table>
<thead>
<tr>
<th>Making Claims</th>
</tr>
</thead>
</table>
| **(7e)** The lesson explicitly states that **students** will make a claim about the ability of a solution to solve a problem. When doing so they are required to cite relevant evidence about how it meets the criteria and constraints of the problem. | The lesson states that **students** will make a claim about the ability of a solution to solve a problem, but does not specify that evidence is required to show how it meets the criteria and constraints of the problem. Using evidence may be implicit and/or necessary for the completion of the lesson.  
**Recommendation:** Make it explicit within the lesson that students must use evidence to back up their claim.  
OR  
The lesson states that **teachers** make a claim about the ability of a solution to solve a problem and students cite the evidence that supports it.  
**Recommendation:** Have students make a claim about the ability of a solution to solve a problem and cite relevant evidence. | In the lesson students are not asked to make claims about the ability of a solution to solve a problem. |

<table>
<thead>
<tr>
<th>Critiquing</th>
</tr>
</thead>
</table>
| **(7f)** The lesson explicitly states that **students** will have the opportunity to share their proposed procedure, explanation, or model. Students will provide and receive feedback from their peers in a respectful manner. All feedback is based on relevant evidence or is in the form of a specific question about the proposed procedure, explanation, or model. | The lesson states that **students** will have the opportunity to share their proposed procedure, explanation, or model, but do not provide or receive feedback from their peers. This could include receiving feedback from the **teacher**, not peers.  
**Recommendation:** Make it explicit within the lesson that after students share they will receive feedback from peers based on evidence or by being asked a question. The teacher will not be the sole source of feedback.  
OR  
The lesson states that **students** will give and receive feedback, but does not specify that the feedback is based on relevant evidence or that it is in the form of a specific question about the proposed procedure, explanation, or model.  
**Recommendation:** Include in the lesson the specifics required for feedback. | In the lesson students do not have the opportunity to provide and/or receive critiques from peers. |

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Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
### SEP #8: Obtaining, Evaluating, and Communicating Information

**Lesson Evaluation Rubric for 3rd-5th Grade**

1) Does the lesson involve **students** obtaining or communicating information?

   - If yes, continue to question 2.
   - If no, the SEP “Obtaining, Evaluating, and Communicating Information” is not part of this lesson.

2) Does the lesson state that **students** will be doing at least one of the following?

   a. Reading grade appropriate complex texts and other media
   b. Obtaining and combining information from books and/or other media to explain phenomena or solutions to design problems
   c. Communicating scientific and/or technical information orally and/or in written formats
   d. Combining and/or comparing information in written texts and other media to support engagement in other SEPs

   - If at least one of the above is stated, continue to question 3.
   - If no, the SEP “Obtaining, Evaluating, and Communicating Information” is not present in this lesson or it is present at a different grade band. Please see Appendix F of the NGSS for more information on grade band expectations.

3) Does the lesson connect to at least one 3rd-5th grade Disciplinary Core Idea (DCI) and/or one CCC (Crosscutting Concept)? For a list of DCIs and CCCs please reference the NGSS available online at [www.nextgenscience.org](http://www.nextgenscience.org)

   - If yes, continue to the rubric.
   - If no, this lesson is not fully aligned to this SEP. A fully aligned lesson combines content and practice. Connect this lesson to a DCI and/or CCC for full alignment

   In addition to answering yes to the first three questions a lesson must fall under “Fully Aligned” in at least one area of the rubric to be considered aligned to the NGSS.

   If the lesson does not contain any aspects in the “Fully Aligned” column it is not considered aligned to the NGSS.

   Follow the recommendations in the “Partially Aligned” column to help align the lesson. These are often small shifts within the lesson.

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Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
<table>
<thead>
<tr>
<th>Obtaining Information</th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clarification Statement:</strong> Reliable media can include informational websites, newspapers, magazines, papers, symposia, or lectures.</td>
<td>(8a) The lesson explicitly states that students will read and comprehend grade-appropriate complex texts and/or other reliable media. From the reading students will summarize and obtain scientific and technical ideas and describe how they are supported by evidence.</td>
<td>The lesson states that students will read and comprehend grade-appropriate complex texts and/or other reliable media, but does ask students to, • Summarize scientific and technical ideas and/or • Obtain scientific and technical ideas and/or • Describe how scientific and technical ideas are supported by evidence <strong>Recommendation:</strong> Make these three expectations explicit in the lesson and add in any missing expectations. OR In the lesson the teacher is reading complex texts and/or other reliable media. The teacher may also be summarizing and/or obtaining scientific and technical ideas and/or describing how scientific and technical ideas are supported by evidence for their students. <strong>Recommendation:</strong> Change the lesson so that students are doing the reading, summarizing, obtaining ideas and describing how they are supported by evidence.</td>
<td>In the lesson students are not reading grade-appropriate complex text and/or other reliable media.</td>
</tr>
<tr>
<td>(8b) The lesson explicitly states that students will find and combine information from books and/or other reliable media to help them understand and explain a phenomena or to help them design solutions to problems.</td>
<td>In the lesson the teacher is finding and/or combining information from books and/or other reliable media to help their students understand and explain a phenomena or to help them design solutions to problems. <strong>Recommendation:</strong> Alter the lesson so that students are in charge of finding and combining information then using it to help themselves understand and explain a phenomena or design a solution to a problem. OR The lesson does not state that students will find and/or combine information from books and/or other reliable media to help them understand and explain a phenomena or to help them design solutions to problems but doing so is implied and/or necessary to complete the lesson. <strong>Recommendation:</strong> Make it explicit. State in the lesson that students will be finding information on their own from books and/or other reliable media and using it to understand a phenomena or design a solution.</td>
<td>In the lesson students are not finding and/or combining information from books and/or other reliable media.</td>
<td></td>
</tr>
</tbody>
</table>

Unless otherwise noted all rubric material is adapted from *Appendix F: Science and Engineering Practices* in the NGSS found in the Next Generation Science Standards (NRC, 2013).
### SEP Rubric #8: Obtaining, Evaluating, and Communicating Information Rubric (continued)

<table>
<thead>
<tr>
<th>Communicating Information</th>
<th>Fully Aligned</th>
<th>Partially Aligned</th>
<th>Not Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td>(8c) The lesson explicitly states that students will share scientific and/or technical information orally and/or in written formats. This could include various written and oral formats, media, tables, diagrams, and charts.</td>
<td>The lesson states that students will share scientific and/or technical information but does not specify the format in which they will do so. <strong>Recommendation:</strong> Add to the lesson how students will share information. Be sure to include whether it is written and/or spoken.</td>
<td>The lesson does not give students the opportunity to share scientific and/or technical information orally or in a written format.</td>
<td></td>
</tr>
<tr>
<td>Supporting other SEPs</td>
<td><strong>Clarification Statement:</strong> Finding and evaluating information in text is a skill that can easily be combined with other SEPs. For example, students may compare several texts and use them as evidence when constructing an argument or combine scientific ideas from text to help solve design problems.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8d) The lesson explicitly states that students will be comparing and/or combining complex text and/or other reliable media when engaging in other SEPs.</td>
<td>In the lesson the teacher is comparing and/or combining complex texts and/or other reliable media to help students engage in other SEPs. <strong>Recommendation:</strong> Alter the lesson so that students will be the ones comparing and/or combining complex text and/or other reliable media. OR The lesson states that students will be using complex text and/or other reliable media, but only in the obtaining, evaluating, and communicating information SEP. <strong>Recommendation:</strong> Include these skills as a part of another SEP. Specify in the lesson how using complex texts helps engagement in the other SEP.</td>
<td>In the lesson students are not engaging in any other SEPs.</td>
<td></td>
</tr>
<tr>
<td>(8e) The lesson explicitly states that students will combine information found in written text and the corresponding tables, diagrams, and/or charts to support engagement in other SEPs.</td>
<td>In the lesson the teacher is combining information found in written text and the corresponding tables, diagrams, and/or charts to help support their students’ engage in other SEPs. <strong>Recommendation:</strong> Alter the lesson so that students will be the ones to combine information found in written text and the corresponding tables, diagrams, and/or charts when engaging in other SEPs. OR The lesson states that students will combine information found in written text and the corresponding tables, diagrams, and/or charts, but only in the obtaining, evaluating, and communicating information SEP. <strong>Recommendation:</strong> Include these skills as a part of another SEP. Specify in the lesson how doing so helps engagement in the other SEP.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Crosscutting Concepts


1. **Patterns.** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

2. **Cause and effect: Mechanism and explanation.** Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

3. **Scale, proportion, and quantity.** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system’s structure or performance.

4. **Systems and system models.** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

5. **Energy and matter: Flows, cycles, and conservation.** Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems’ possibilities and limitations.

6. **Structure and function.** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

7. **Stability and change.** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
Disciplinary Core Ideas for Grades 3-5

More information and a complete description of DCIs can be found at http://www.nextgenscience.org/search-standards-dci

3rd Grade
Physical Science
PS2.A: Forces and Motion
PS2.B: Types of Interactions
Life Science
LS2.A: Growth and Development of Organisms
LS2.B: Ecosystem Dynamics, Functioning, and Resilience
LS2.D: Social Interactions and Group Behavior
LS2.A: Inheritance of Traits
LS2.B: Variation of Traits
LS4.A: Evidence of Common Ancestry and Diversity
LS4.B: Natural Selection
LS4.C: Adaptation
LS4.D: Biodiversity and Humans
Earth Systems Science
ESS2.C: The Role of Water in Earth’s Surface Processes
Engineering Design
ETS1.A: Defining and Delimiting Engineering Problems
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution

4th Grade
Physical Science
PS3.A: Definitions of Energy
PS3.B: Conservation of Energy and Energy Transfer
PS3.C: Relationship Between Energy and Forces
PS3.D: Energy in Chemical Processes and Everyday Life
PS4.A: Wave Properties
PS4.B: Electromagnetic Spectrum
PS4.C: Information Technologies and Instrumentation
Life Science
LS1.A: Structure and Function
LS1.D: Information Processing
Earth Systems Science
ESS1.C: The History of Planet Earth
ESS2.A: Earth Materials and Systems
ESS2.B: Plate Tectonics and Large-Scale System Interactions
ESS2.E: Biogeology
ESS3.A: Natural Resources
ESS3.B: Natural Hazards

Unless otherwise noted all rubric material is adapted from Appendix F: Science and Engineering Practices in the NGSS found in the Next Generation Science Standards (NRC, 2013).
Engineering Design
ETS1.A: Defining and Delimiting Engineering Problems
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution

5th Grade
Physical Science
PS1.B: Chemical Reactions
PS2.B: Types of Interactions
PS3.D: Energy in Chemical Processes and Everyday Life

Life Science
LS2.A: Interdependent Relationships in Ecosystems
LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

Earth System Science
ESS1.A: The Universe and its Stars
ESS1.B: Earth and the Solar System
ESS2.A: Earth Materials and Systems
ESS2.C: The Roles of Water in Earth’s Surface Processes
ESS3.C: Human Impacts on Earth Systems

Engineering Design
ETS1.A: Defining and Delimiting Engineering Problems
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution

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References


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Appendix B

Suggestions to Improve Alignment of Expedition: Yellowstone! Curriculum

A matrix containing suggestions for improved alignment begins on the following page. Suggestions are separated by unit. The matrix lists from right to left, (a) the lesson name, (b) SEPs the lesson is fully aligned to, (c) SEPs the lesson is partially aligned to, and (d) suggestions to move the partially aligned SEPs to fully aligned. All suggestions were gleaned from the SEP rubrics (Appendix A).
### Unit 1: Yellowstone’s Legacy

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Fully Aligned SEPs</th>
<th>Partially Aligned SEPs</th>
<th>Recommendations for Full Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your Park-Your Responsibility</td>
<td>SEP #2: Developing and Using Models</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>SEP #6: Constructing Explanations and Designing Solutions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Read All About It!</td>
<td>None</td>
<td>SEP #7: Engaging in Argument from Evidence</td>
<td>1) When students are reading articles have them determine which parts of it are facts, reasoned judgments based on research findings, and speculation. OR 2) After students present their article this lesson encourages teachers to let other students offer their perspectives. Add to the lesson that students must back up their perspective with evidence.</td>
</tr>
<tr>
<td>Reins to Trains</td>
<td>SEP #6: Constructing Explanations and Designing Solutions</td>
<td>None</td>
<td>To meet this SEP the newspaper articles must include some science, technology, or engineering. In addition to summarizing the article, students need to pick out the scientific, engineering, and/or technical ideas and describe how they are supported with evidence.</td>
</tr>
<tr>
<td>Yellowstone of Yesteryear</td>
<td>None</td>
<td>SEP #1: Asking Questions and Defining Problems</td>
<td>The beginning of this lesson asks students to imagine a 5-day trip through YNP in the late 1800s then asks them to consider a series of questions. Instead of prompting students, allow them to come up with their own questions about YNP and brainstorm the possible answers.</td>
</tr>
</tbody>
</table>
## Unit 1: Yellowstone’s Legacy (continued)

<table>
<thead>
<tr>
<th>Activity</th>
<th>SEP #2: Developing and Using Models</th>
<th>SEP #6: Constructing Explanations and Designing Solutions</th>
<th>SEP #8: Obtaining, Evaluating, and Communicating Information</th>
<th>SEP #7: Engaging in Argument from Evidence</th>
<th>SEP #6: Constructing Explanations and Designing Solutions</th>
<th>SEP #8: Obtaining, Evaluating, and Communicating Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Museum History Hunt</strong></td>
<td></td>
<td>In designing the museum exhibits students are designing a solution to the problem, how can I best display my EY experience and learning to others? Before designing present this problem to students and have them establish the criteria for success (what the exhibit needs to clearly communicate the experience) and constraints (how much time can this take, what materials are allowed, the size of the exhibit, etc.). Once exhibits are finished have students discuss how well each one fits the established criteria and constraints.</td>
<td>Require students to include and present something in their exhibit that relates to science, engineering, or technology.</td>
<td>Students are already making claims about the best solution to a problem, but they are not required to use evidence to explain why their solution is best. Make the use of evidence explicit.</td>
<td>The teacher facilitates several discussions about YNP. Add to the lesson that in these discussions students must use evidence when presenting their answers.</td>
<td>Require students to include and present something in their exhibit that relates to science, engineering, or technology.</td>
</tr>
<tr>
<td><strong>Dueling Mandates</strong></td>
<td>SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>SEP #7: Engaging in Argument from Evidence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>You Be the Judge</strong></td>
<td>None</td>
<td>SEP #6: Constructing Explanations and Designing Solutions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Unit 2: Voices from the Past

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Fully Aligned SEPs</th>
<th>Partially Aligned SEPs</th>
<th>Recommendations for Full Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellowstone in Time</td>
<td>None</td>
<td>SEP #7: Engaging in Argument from Evidence</td>
<td>Make the use of evidence explicit. When students claim they have the earliest event have them state why they believe it is the earliest.</td>
</tr>
<tr>
<td>Chants of a Lifetime</td>
<td>SEP #1: Asking Questions and Defining Problems  SEP #6: Constructing Explanations and Designing Solutions  SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sharing a Story</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Trappers, Traders, and Top Hats</td>
<td>SEP #2: Developing and Using Models  SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>SEP #6: Constructing Explanations and Designing Solutions</td>
<td>In activity 3 have students identify and explain the adaptations beavers have for living in an aquatic environment. In the discussion, require students to use evidence to back up their reasoning about adaptations.</td>
</tr>
<tr>
<td>The Nation Cries Out</td>
<td>SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Speak Loudly and Carry a Big Stick</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Overcoming 70 Years of Silence</td>
<td>None</td>
<td>SEP #7: Engaging in Argument from Evidence  SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>More detail about the structure of the debate is needed. Students are making claims but the use of evidence to back up those claims is implied not explicit. Make the use of evidence explicit and highlight it’s importance in this activity.  Give students grade appropriate complex texts to interpret and use as evidence as they are preparing for the debate.</td>
</tr>
<tr>
<td>Postmarked Yellowstone!</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Expressing the Wonders</td>
<td>None</td>
<td>SEP #6: Constructing Explanations and Designing Solutions</td>
<td>In step 1, students suggest and discuss what the area around YNP was like before it was YNP. Require students to use evidence when presenting their explanation for the landscape.</td>
</tr>
<tr>
<td>Painting 1000 Words</td>
<td>None</td>
<td>SEP #7: Engaging in Argument from Evidence</td>
<td>In step 9, students are asked how their watercolor painting could convince a group to protect an area. They are making a claim, but not necessarily supporting it with evidence. Require students to use evidence when presenting their claim.</td>
</tr>
</tbody>
</table>
## Unit 3: Geologic Wonders

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Fully Aligned SEPs</th>
<th>Partially Aligned SEPs</th>
<th>Recommendations for Full Alignment</th>
</tr>
</thead>
</table>
| Through the Ages        | SEP #2: Developing and Using Models  
SEP #6: Constructing Explanations and Designing Solutions | In the discussion in activity 3, require students to use evidence when looking at YNP through time. Emphasize they “why?”  
Students can use their journal entries from the previous activities as evidence. |
| Landscaping with Wind & Water | SEP #2: Developing and Using Models  
SEP #3: Planning and Carrying Out Investigations  
SEP #6: Constructing Explanations and Designing Solutions | In Activity 2 when interviewing a tree, have the student that is the tree answer the questions using physical evidence on or near the tree, not just their imagination. |
| Testing the Waters      | SEP #2: Developing and Using Models  
SEP #3: Planning and Carrying Out Investigations  
SEP #4: Analyzing and Interpreting Data  
SEP #5: Using Mathematics and Computational Thinking  
SEP #6: Constructing Explanations and Designing Solutions  
SEP #8: Obtaining, Evaluating, and Communicating Information  
SEP #1: Asking Questions and Defining Problems |                                                                 |

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Fully Aligned SEPs</th>
<th>Partially Aligned SEPs</th>
<th>Recommendations for Full Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who Am I?</td>
<td>SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>A Bear's Menu</td>
<td>SEP #5: Using Mathematics and Computational Thinking</td>
<td>SEP #2: Developing and Using Models</td>
<td>In activity 1, have students come up with their own representation of what bears eat by season instead of using the circle divided into four quarters or copying from the handout.</td>
</tr>
<tr>
<td>To Prey or Not to Prey</td>
<td>SEP #6: Constructing Explanations and Designing Solutions SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>SEP #2: Developing and Using Models</td>
<td>In this simulation of a food web the teacher has developed it and students are using it. To be fully aligned, have the students develop the model from scratch or identify the limitations of the model.</td>
</tr>
<tr>
<td>Tell-Tale Animal Signs</td>
<td>SEP #3: Planning and Conducting Investigations SEP #4: Analyzing and Interpreting Data SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Whose Teeth are These?</td>
<td>SEP #3: Planning and Conducting Investigations SEP #4: Analyzing and Interpreting Data SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>SEP #2: Developing and Using Models</td>
<td>In this simulation of an animal’s mouth the teacher has developed it and students are using it. To be fully aligned, have the students develop the model from scratch or identify the limitations of the model.</td>
</tr>
<tr>
<td>Invent an Animal</td>
<td>SEP #2: Developing and Using Models SEP #4: Analyzing and Interpreting Data SEP #6: Constructing Explanations and Designing Solutions SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Yellowstone Tree Key</td>
<td>SEP #2: Developing and Using Models SEP #3: Planning and Carrying Out Investigations SEP #4: Analyzing and Interpreting Data SEP #6: Constructing Explanations and Designing Solutions SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
## Unit 4: Ecological Communities (continued)

<table>
<thead>
<tr>
<th>Activity</th>
<th>SEPs</th>
<th>None</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recording Wildlife</strong></td>
<td>SEP #3: Planning and Carrying Out Investigations&lt;br&gt;SEP #4: Analyzing and Interpreting Data&lt;br&gt;SEP #6: Constructing Explanations and Designing Solutions&lt;br&gt;SEP #7: Engaging in Argument from Evidence&lt;br&gt;SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Making Tracks</strong></td>
<td>SEP #3: Planning and Carrying Out Investigations&lt;br&gt;SEP #4: Analyzing and Interpreting Data&lt;br&gt;SEP #5: Using Mathematics and Computational Thinking</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Winter Survival</strong></td>
<td>None</td>
<td>SEP #2: Developing and Using Models</td>
<td>The active/inactive freeze tag game is a simulation, but it is teacher directed. For this lesson to be fully aligned to SEP #2 the students must identify the limitations of this model.</td>
</tr>
<tr>
<td><strong>Wild Wapiti</strong></td>
<td>SEP #4: Analyzing and Interpreting Data&lt;br&gt;SEP #5: Using Mathematics and Computational Thinking&lt;br&gt;SEP #6: Constructing Explanations and Designing Solutions</td>
<td>SEP #2: Developing and Using Models</td>
<td>This game is a type of a model but it is teacher directed. For this lesson to be fully aligned to SEP #2 the students must identify the limitations of this model.</td>
</tr>
<tr>
<td><strong>On Fire!</strong></td>
<td>SEP #3: Planning and Carrying Out Investigations&lt;br&gt;SEP #4: Analyzing and Interpreting Data&lt;br&gt;SEP #6: Constructing Explanations and Designing Solutions</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Out of the Fire</strong></td>
<td>SEP #1: Asking Questions and Defining Problems&lt;br&gt;SEP #3: Planning and Carrying Out Investigations&lt;br&gt;SEP #4: Analyzing and Interpreting Data&lt;br&gt;SEP #5: Using Mathematics and Computational Thinking&lt;br&gt;SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Talking Trees</strong></td>
<td>SEP #2: Developing and Using Models&lt;br&gt;SEP #3: Planning and Carrying Out Investigations&lt;br&gt;SEP #4: Analyzing and Interpreting Data&lt;br&gt;SEP #5: Using Mathematics and Computational Thinking&lt;br&gt;SEP #8: Obtaining, Evaluating, and Communicating Information</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
## Unit 4: Ecological Communities (continued)

| Waters of Life | SEP #2: Developing and Using Models  
SEP #3: Planning and Carrying Out Investigations  
SEP #4: Analyzing and Interpreting Data  
SEP #8: Obtaining, Evaluating, and Communicating Information | SEP #1: Asking Questions and Defining Problems  
SEP #6: Constructing Explanations and Designing Solutions | After activity 1, have students generate testable questions based on what they observed and recorded in the riparian area.  
At the end of the activity 2, when asking what connections can be made between aquatic and riparian plant and animal communities, ask students to explain their reasoning using evidence from their investigation. |
Appendix C

Sample Lesson from Expedition: Yellowstone! Curriculum

*Waters of Life* lesson from Unit 4: Ecological Communities.
Waters of Life

Materials
Survey of Riparian Area, pencils, journals, watercolors, magnifying lenses, waders, trays for holding invertebrates, nets, tweezers, eye droppers, rulers, data sheets, field guides, Invertebrate Record sheet, water test kits

Background
Within Yellowstone National Park, there are more than 200 lakes, with a total of 107,000 surface acres of water, and 1,000 streams, for a total of 2,650 miles of running water. Yellowstone’s riparian and aquatic environments are key elements to the foundation for its healthy ecosystem. Yellowstone’s water systems provide quality habitat for native and nonnative fish, which in turn are an important food source for many of its animals, including bears, eagles, otters, mink, ospreys, pelicans, loons, grebes, mergansers, diving ducks, terns, gulls, kingfishers, and herons.
Suggested Procedure for Activity 1: 
By the Water

The park ranger will:

1. Gather students into a large group in an area overlooking a creek.

2. Ask the students to focus on the area that runs along the edge of the creek. Have them describe what they see. Ask them how that specific area is different from the area that extends beyond it.

3. Explain that this type of habitat is called a riparian area and discuss its importance.

4. Instruct small groups to record their observations on the Survey of a Riparian Area handout as they explore the riparian area. Ask them to write and draw detailed information on their surveys. Explain that detailed and accurate documentation of observations are valuable scientific records.

5. Advise students to be careful when exploring riparian areas. At least one adult must accompany each group of students.
### Survey of a Riparian Area

**Student Handout**

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
<th>Time</th>
<th>Weather</th>
</tr>
</thead>
</table>

Before you record your observations of the riparian area, find a starting point and draw the course of the creek on the back of this sheet. As you walk along the creek, draw and label your observations where they belong on your map. Beside each item listed below, you may wish to record detailed observations.

| Insects | Leaves in water | Sagebrush | Rocks in water | Rocks along the bank | Rocks with sharp edges | Rounded rocks | Things floating in the stream | Colors in the creek | Moss | Bird nests | Birds in trees | Bushes | Willows | Grasses on the bank | Grasses growing in the water | Animal life in the water | Bones | Animal burrows | Scat | Tracks | Sounds | Water flow at logjams | Multiple water depths | Evidence of water level changes | Appearance of the bank | Location and number of willows | Soil types (solid, sandy, muddy) | Variation in soil type | Largest tree | Other |
Suggested Procedure for Activity 2: In the Water

The park ranger will:

1. Discuss the importance of sampling water systems for aquatic organisms. Explain to students how they will work in groups to collect and identify aquatic invertebrates. Ask students to work carefully along the stream bank to minimize their impact to the vegetation and sides of the stream. Remind students to stay with an adult at all times and follow safety rules.

2. Select a section of stream where the water is shallow and fast moving and where the bottom is made up of cobble or gravel. Ask a student to place one edge of the net on the stream bottom, downstream from the sampling area. Using waders, have a second student disturb the area immediately upstream of the net by shuffling his/her feet along the stream bottom. This will allow invertebrates to flow into the net. Have a student carefully remove the net from the stream bottom. Transfer the contents of the net into the trays with some water to keep the insects alive. Make sure the net is thoroughly cleaned of even the smallest insects and all the materials are separated across the tray.

3. Ask students to identify the invertebrates by using the field guides and record them on the Invertebrate Record sheet. Ask students to keep track of the number of each specimen found. As soon as the students are finished, ask them to carefully return the specimens to the stream.

4. Collect sampling equipment and distribute Data Sheets and water test kits. Ask each group to read the tables on the Data Sheets indicating temperatures, pH ranges, and dissolved oxygen levels. Ask them to look at the list of aquatic organisms they found, and based on what they collected and identified, ask them to predict what they think are the stream's temperature, pH, and dissolved oxygen levels. Assist students with reading tables for information, if necessary.

5. Ask students to record their predictions on the bottom of the Invertebrate Record sheet. Explain how to measure the temperature, pH, and dissolved oxygen of the stream. Have them record the measurements next to their predictions.

6. Discuss students' findings. Ask the students to share the types of aquatic organisms found, and then ask them to discuss their predictions and test results. Ask the students to talk about what they have learned.

7. Ask students what connections there are, if any, between the aquatic and riparian plant and animal communities.
Invertebrate Record Sheet
Student Handout

<table>
<thead>
<tr>
<th>Type of Invertebrate</th>
<th>Number Found</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

Predictions of Water Characteristics
Study the tables for temperatures, pH ranges, and dissolved oxygen levels. Based on the aquatic organisms you found, predict the water characteristics of the stream.

<table>
<thead>
<tr>
<th></th>
<th>Measurement</th>
<th>Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Data Sheet
Student Handout

Approximate Temperature Ranges Required for Organisms

<table>
<thead>
<tr>
<th>Water Temperature (Fahrenheit)</th>
<th>Example of Life</th>
</tr>
</thead>
</table>
| Greater than 68°F (warm)      | • Much plant life, many fish diseases  
                                 • Mostly bass, crappie, bluegill, carp, catfish,  
                                   caddis fly |
| Middle range of 55°F to 68°F  | • Some plant life, some fish diseases  
                                 • Salmon, trout, stone fly, mayfly, caddis fly,  
                                   water beetles |
| Low range of less than 55°F (cool) | • Little plant life  
                                • Trout, caddis fly, stone fly, mayfly |

ph Ranges Supporting Aquatic Life

<table>
<thead>
<tr>
<th></th>
<th>Most Acid</th>
<th>Neutral</th>
<th>Most Alkaline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbes</td>
<td>1.0</td>
<td>6.5</td>
<td>13</td>
</tr>
<tr>
<td>Plants, algae, rooted, etc.</td>
<td>6.5</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Carps, suckers, catfish,</td>
<td>6.0</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>Bass, crappie</td>
<td>6.5</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>Snails, clams, mussels</td>
<td>7.0</td>
<td>9.0</td>
<td></td>
</tr>
</tbody>
</table>
| Largest variety of animals—  trout, mayfly, stone fly,  
                              caddis fly  | 6.5       | 7.5     |               |

Dissolved Oxygen Requirements for Native Fish and Other Aquatic Life

<table>
<thead>
<tr>
<th>Example of Life</th>
<th>D.O. in part per million or milligrams per liter</th>
</tr>
</thead>
</table>
| Cold-water organisms including salmon and trout,  
  caddis fly, stone fly, mayfly (below 68°F—  
  spawning, growth, and well-being) | 6 ppm and above |
| Warm-water organisms including game fish such as bass,  
  crappie, catfish, carp, and some caddis fly (above 68°F.)  
  Note: Pure, cold water can hold a maximum of 16 ppm under field conditions. | 5 ppm and above |
### Appendix D

**List of Frequently Used Acronyms**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAAS</td>
<td>American Association for the Advancement of Science</td>
</tr>
<tr>
<td>CCC</td>
<td>Crosscutting Concept</td>
</tr>
<tr>
<td>DCI</td>
<td>Disciplinary Core Idea</td>
</tr>
<tr>
<td>EE</td>
<td>Environmental Education</td>
</tr>
<tr>
<td>EY</td>
<td>Expedition: Yellowstone!</td>
</tr>
<tr>
<td>NCLB</td>
<td>No Child Left Behind Act of 2001</td>
</tr>
<tr>
<td>NGSS</td>
<td>Next Generation Science Standards</td>
</tr>
<tr>
<td>NPS</td>
<td>National Park Service</td>
</tr>
<tr>
<td>NSES</td>
<td>National Science Education Standards</td>
</tr>
<tr>
<td>PE</td>
<td>Performance Expectations</td>
</tr>
<tr>
<td>REE</td>
<td>Residential Environmental Education</td>
</tr>
<tr>
<td>SEP</td>
<td>Science and Engineering Practice</td>
</tr>
<tr>
<td>STEM</td>
<td>Science, Technology, Engineering and Mathematics</td>
</tr>
<tr>
<td>YNP</td>
<td>Yellowstone National Park</td>
</tr>
</tbody>
</table>