TOWNSHIP OF UNION PUBLIC SCHOOLS

8th Grade Science

Curriculum Guide

2016

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Science

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Mission Statement

The mission of the Township of Union Public Schools is to build on the foundations of honesty, excellence, integrity, strong family, and community partnerships. We promote a supportive learning environment where every student is challenged, inspired, empowered, and respected as diverse learners. Through cultivation of students' intellectual curiosity, skills and knowledge, our students can achieve academically and socially, and contribute as responsible and productive citizens of our global community.

Philosophy Statement

The Township of Union Public School District, as a societal agency, reflects democratic ideals and concepts through its educational practices. It is the belief of the Board of Education that a primary function of the Township of Union Public School System is the formulation of a learning climate conducive to the needs of all students in general, providing therein for individual differences. The school operates as a partner with the home and community.

Science Department Mission

The goal of the Union Township Science Department is to expose students to the different branches of science through the use of labs, modern technology, and field experiences. We aspire to develop scientific literacy in all students, allowing them to utilize problem solving and critical thinking skills. Students are encouraged to untap their potential by engaging in inquiry-based activities and experiments. When students develop a deep understanding of science they can truly appreciate the world in which they live.

Science Department Vision

We aspire to encourage creativity and imagination, as it allows students to explore the world around them on their own. Our classrooms are conducive to student learning and our activities are student centered. At Union Township we expect highly of our staff and students and uphold them to high standards. We would like to see students pursue science in college, their career choice, or personal interests.

Statement of District Goals

- Develop reading, writing, speaking, listening, and mathematical skills.
- Develop a pride in work and a feeling of self-worth, self-reliance, and self discipline.
- Acquire and use the skills and habits involved in critical and constructive thinking.
- Develop a code of behavior based on moral and ethical principals.
- Work with others cooperatively.
- Acquire a knowledge and appreciation of the historical record of human achievement and failures and current societal issues.
- Acquire a knowledge and understanding of the physical and biological sciences.
- Participate effectively and efficiently in economic life and the development of skills to enter a specific field of work.
- Appreciate and understand literature, art, music, and other cultural activities.
- Develop an understanding of the historical and cultural heritage.
- Develop a concern for the proper use and/or preservation of natural resources.
- Develop basic skills in sports and other forms of recreation.

Course Description

The eighth grade curriculum elaborates upon and deepens the concepts presented in grades six and seven. This "spiral of knowledge" engenders the continuity of connections among scientific concepts.

During the physical science unit, students will investigate different forms of energy and the relationships that exist between energy and forces. Students will also focus on the Law of Conservation of Energy to realize that the amount of energy within a system will not change but rather be transformed from one form to another. In addition, students will study the electromagnetic spectrum to understand the properties of waves.

During the life science unit, students will study structural relationships among organisms to understand and intertwine the concepts of natural selection, adaptation, and evolution. Students will continue their study with focus on the impacts that human activities have on our natural resources of land, energy, minerals, and water.

This course is designed to integrate the three dimensions of scientific and engineering practices, crosscutting concepts, and core ideas. This will enable students to engage in a multifaceted approach to inquiry based learning. The eighth grade science curriculum is just a link in the chain of knowledge that will allow our students to be empowered, life time learners.

Course Proficiencies- Eighth Grade Science

Unit 1: Evidence of a Common Ancestry

- Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. MS-LS4-1
- Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. MS-LS4-2
- Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy MS-LS4-3

Unit 2: Selection and Adaptation

- Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. MS-LS4-4
- Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. MS-LS4-5
- Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. MS-LS4-6.

Unit 3: Stability and Change on Earth

- Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes MS-ESS3-1
- Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. MS-ESS3-2
- Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. MS-ESS3-4
- Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. MS-ESS3-5

Unit 4: Human Impact

- Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. MS-ESS3-3
- Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. MS-ETS1-1

- Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. MS-ETS1-2
- Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. MS-ETS1-3.

Unit 5: Relationships among Forms of Energy

- Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. MS-PS3-1
- Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. MS-PS3-2
- Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object MS-PS3-5

Unit 6: Thermal Energy

- Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. MS-PS3-3
- Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. MS-PS3-4
- Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. MS-ETS1-1
- Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. MS-ETS1-2
- Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. MS-ETS1-3
- Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved MS-ETS1-4

Unit 7: The Electromagnetic Spectrum

- Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. MS-PS4-1
- Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. MS-PS4-2
- Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals MS-PS4-3

Curriculum Units – Eighth Grade Science

- **Unit 1**: Evidence of Common Ancestry
- **Unit 2**: Selection and Adaptation
- **Unit 3**: Stability and Change on Earth
- **Unit 4**: Human Impacts on Earth Systems and Global Climate Change
- **Unit 5**: Relationships Among Forms of Energy
- **Unit 6**: Thermal Energy
- **Unit 7**: The Electromagnetic Spectrum

Pacing Guide- Eighth Grade Science

Unit 1: Evidence of a Common Ancestry **Instructional Days: 15**

In this unit of study, students analyze graphical displays and gather evidence from multiple sources in order to develop an understanding of how fossil records and anatomical similarities of the relationships among organisms and species describe biological evolution. Students search for patterns in the evidence to support their understanding of the fossil record and how those patterns show relationships between modern organisms and their common ancestors. The crosscutting concepts of *cause and effect, patterns*, and *structure and function* are called out as organizing concepts for these disciplinary core ideas. Students use the practices of *analyzing graphical displays* and *gathering, reading, and communicating information.* Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-LS4-1, MS-LS4-2, and MS-LS4-3.

Unit 2: Selection and Adaptation **Instructional Days: 20**

Students construct explanations based on evidence to support fundamental understandings of natural selection and evolution. They will use ideas of genetic variation in a population to make sense of how organisms survive and reproduce, thus passing on the traits of the species. The crosscutting concepts of *patterns* and *structure and function* are called out as organizing concepts that students use to describe biological evolution. Students use the practices of *constructing explanations, obtaining, evaluating, and communicating information*, and *using mathematical and computational thinking*. Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-LS4-4, MS-LS4-5, and MS-LS4-6.

Unit 3: Stability and Change on Earth **Instructional Days: 30**

Students construct an understanding of the ways that human activities affect Earth's systems. Students use practices to understand the significant and complex issues surrounding human uses of land, energy, mineral, and water resources and the resulting impacts on the development of these resources. Students also understand that the distribution of these resources is uneven due to past and current geosciences processes or removal by humans. The crosscutting concepts of *patterns, cause and effect*, and *stability and change* are called out as organizing concepts for these disciplinary core ideas. In this unit of study students are expected to demonstrate proficiency in *asking questions, analyzing and interpreting data, constructing explanations, and designing solutions.* Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-ESS3-1, MS-ESS3-2, MS-ESS3-4, and MS-ESS3-5.

Unit 4: Human Impacts **Instructional Days: 25**

In this unit of study, students analyze and interpret data and design solutions to build on their understanding of the ways that human activities affect Earth's systems. The emphasis of this unit is the significant and complex issues surrounding human uses of land, energy, mineral, and water resources and the resulting impacts of these uses. The crosscutting concepts of *cause and effect* and *the influence of science, engineering, and technology on society and the natural world* are called out as organizing concepts for these disciplinary core ideas.
Building on Unit 3, students define a problem by precisely specifying criteria and constraints for solutions as well as potential impacts on society and the natural environment; systematically evaluate alternative solutions; analyze data from tests of different solutions; combining the best ideas into an improved solution; and develop and iteratively test and improve their model to reach an optimal solution. In this unit of study students are expected to demonstrate proficiency in *analyzing and interpreting data* and *designing solutions.* Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-ESS3-3, MS-ETS1-1, MS-ETS1-2, and MS-ETS1-3.

Unit 5: Relationships among Forms of Energy **Instructional Days: 20**

In this unit, students use the practices of *analyzing and interpreting data, developing and using models*, and *engaging in argument from evidence* to make sense of relationship between energy and forces. Students develop their understanding of important qualitative ideas about the conservation of energy. Students understand that objects that are moving have kinetic energy and that objects may also contain stored (potential) energy, depending on their relative positions. Students also understand the difference between energy and temperature, and the relationship between forces and energy. The crosscutting concepts of *scale, proportion, and quantity, systems and system models*, and *energy and matter* are called out as organizing concepts for these disciplinary core ideas. Students use the practices of *analyzing and interpreting data, developing and using models*, and *engaging in argument from evidence.* Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-PS3-1, MS-PS3-2, and MS-PS3-5.

Unit 6: Thermal Energy **Instructional Days: 30**

In this unit, students *ask questions, plan and carry out investigations, engage in argument from evidence, analyze and interpret data, construct explanations, define problems and design solutions* as they make sense of the difference between energy and temperature. They use the practices to make sense of how the total change of energy in any system is always equal to the total energy transferred into or out of the system. The crosscutting concepts of *energy and matter, scale, proportion, and quantity*, and *influence of science, engineering, and technology on society and the natural world* are the organizing concepts for these disciplinary core ideas. Students ask *questions, plan and carry out investigations, engage in argument from evidence, analyze and interpret data, construct explanations, define problems and design solutions.* Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-PS3-3, MS-PS3-4, MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, and MS-ETS1-4.

Unit 7: The Electromagnetic Spectrum **Instructional Days: 20**

In this unit of study, students *develop and use models, use mathematical thinking,* and *obtain, evaluate, and communicate information* in order to describe and predict characteristic properties and behaviors of waves. Students also apply their understanding of waves as a means of sending digital information. The crosscutting concepts of *patterns* and *structure and function* are used as organizing concepts for these disciplinary core ideas. Students *develop and use models, use mathematical thinking,* and *obtain, evaluate, and communicate information.* Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-PS4-1, MS-PS4-2, and MS-PS4-3.

Unit 1: Evidence of Common Ancestry

Unit Summary
How do we know when an organism (fossil) was alive? ***How do we know that birds and dinosaurs are related?*** In this unit of study, students analyze graphical displays and gather evidence from multiple sources in order to develop an understanding of how fossil records and anatomical similarities of the relationships among organisms and species describe biological evolution. Students search for patterns in the evidence to support their understanding of the fossil record and how those patterns show relationships between modern organisms and their common ancestors. The crosscutting concepts of *cause and effect, patterns,* and *structure and function* are called out as organizing concepts for these disciplinary core ideas. Students use the practices of *analyzing graphical displays* and *gathering, reading, and communicating information*. Students are also expected to use these practices to demonstrate understanding of the core ideas. This unit is based on MS-LS4-1, MS-LS4-2, and MS-LS4-3.
Student Learning Objectives
Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. *[Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock*

layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.] **(MS-LS4-1)**
Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. *[Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.]* **(MS-LS4-2)**
Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy. *[Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.]* **(MS-LS4-3)**

Unit Sequence	
Part A: *How do we know when an organism (fossil) was alive?*	
Concepts	**Formative Assessments**
• The fossil record documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. • The collection of fossils and their placement in chronological order as identified through the location of sedimentary layers in which they are found or through radioactive dating is known as the fossil record. • Relative fossil dating is achieved by examining the fossil's relative position in sedimentary rock layers. • Objects and events in the fossil record occur in consistent patterns that are understandable through measurement and observation. • Patterns exist in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in rock layers. • Patterns can occur within one species of organism or across many species.	*Students who understand the concepts can:* • Use graphs, charts, and images to identify patterns within the fossil record. • Analyze and interpret data within the fossil record to determine similarities and differences in findings. • Make logical and conceptual connections between evidence in the fossil record and explanations about the existence, diversity, extinction, and change in many life forms throughout the history of life on Earth.

Unit Sequence	
Part B: *How do we know that birds and dinosaurs are related?*	
Concepts	**Formative Assessments**
• Similarities and differences exist in the gross anatomical structures of modern organisms. • There are anatomical similarities and differences among modern organisms and between modern organisms and fossil organisms. • Similarities and differences exist in the gross anatomical structures of modern organisms and their fossil relatives. • Similarities and differences in the gross anatomical structures of modern organisms enable the reconstruction of evolutionary history and the inference of lines of evolutionary decent. • Patterns and anatomical similarities in the fossil record can be used to identify cause-and-effect relationships. • Science assumes that objects and events in evolutionary history occur in consistent patterns that are understandable through measurement and observation.	*Students who understand the concepts can:* • Apply scientific ideas to construct explanations for evolutionary relationships. • Apply the patterns in gross anatomical structures among modern organisms and between modern organisms and fossil organisms to construct explanations of evolutionary relationships. • Apply scientific ideas about evolutionary history to construct an explanation for evolutionary relationships evidenced by similarities or differences in the gross appearance of anatomical structures.

Unit Sequence	
Part C: *Other than bones and structures being similar, what other evidence is there that birds and dinosaurs are related?*	
Concepts	**Formative Assessments**
• Relationships between embryos of different species show similarities in their development. • General patterns of relatedness among embryos of different organisms can be inferred by comparing the macroscopic appearance of diagrams or pictures. • Pictorial data can be used to identify patterns of similarities in embryological development across multiple species. • Similarities in embryological development across multiple species show relationships that are not evident in the fully formed	*Students who understand the concepts can:* • Use diagrams or pictures to identify patterns in embryological development across multiple species. • Analyze displays of pictorial data to identify where the embryological development is related linearly and where that linear nature ends. • Infer general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.

organisms.	

Connections to Other Units
Grade 7, Unit 6: Inheritance and Variation of Traits • Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. • Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. **Grade 6, Unit 8: Earth Systems** • The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. • Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.

Appendix A: NGSS and Foundations for the Unit
Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. *[Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]* **(MS-LS4-1)**
Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. *[Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.]* **(MS-LS4-2)**
Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy. *[Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.]* **(MS-LS4-3)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data • Analyze displays of data to identify linear and nonlinear relationships. (MS-LS4-3) • Analyze and interpret data to determine similarities and differences in findings. (MS-LS4-1) **Constructing Explanations and Designing Solutions** • Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events. (MS-LS4-2) - - - - - - - - - - **Connections to Nature of Science** **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-LS4-1)	**LS4.A: Evidence of Common Ancestry and Diversity** • The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. (MS-LS4-1) • Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. (MS-LS4-2) • Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. (MS-LS4-3)	**Patterns** • Patterns can be used to identify cause and effect relationships. (MS-LS4-2) • Graphs, charts, and images can be used to identify patterns in data. (MS-LS4-1),(MS-LS4-3) **Cause and Effect** • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS4-4),(MS-LS4-5),(MS-LS4-6) - - - - - - - - - - **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. (MS-LS4-1),(MS-LS4-2)

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (MS-LS4-1),(MS-LS4-2),(MS-LS4-3) **RST.6-8.1** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a	Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. (MS-LS4-1),(MS-LS4-2) **6.EE.B.6**

flowchart, diagram, model, graph, or table). (MS-LS4-1),(MS-LS4-3) **RST.6-8.7** Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-LS4-3) **RST.6-8.9** Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (MS-LS4-2) **WHST.6-8.2** Draw evidence from informational texts to support analysis, reflection, and research. (MS-LS4-2) **WHST.6-8.9** Engage effectively in a range of collaborative discussions (one-on-one, in groups, teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly. (MS-LS4-2) **SL.8.1** Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (MS-LS4-2) **SL.8.4**	

Unit 1: Evidence of a Common Ancestry (15 days)			
This unit is based on:	SLO	Inquiry Menu	Quick Links
MS-LS4-1	Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.	1. Getting Into the Fossil Record 2. What Do You Mean I Can Learn From a Fossil?	1. https://api.betterlesson.com/mtp/lesson/635205/print Link to above website: http://www.ucmp.berkeley.edu/education/explorations/tours/fossil/index.html 2. http://betterlesson.com/lesson/631865/what-do-you-mean-i-can-learn-from-a-fossil
MS-LS4-2	Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.	3. Evidence for Evolution - Fossil Record 4. What Did T-Rex Taste Like?	3. http://betterlesson.com/lesson/638006/evidence-for-evolution-fossil-record 4. http://betterlesson.com/lesson/633888/what-did-t-rex-taste-like
MS-LS4-3	Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.	5. Embryonic Development - Evidence for Evolution 6. *Classroom Explorations:* Zebrafish Development	5. http://betterlesson.com/lesson/637398/embryonic-development-evidence-for-evolution 6. http://www.exploratorium.edu/imaging-station/activities/classroom/zebrafish_dev/ca_zebrafish_dev.php

1. This webquest takes students through various simulations which allows them to understand why some organisms become fossils, while others do not. It provides many examples (such as a mammoth, mouse, and jellyfish) and forces students to draw a comparison between them.
2. This website provides teachers with a short video clip which briefly describes the process of finding and unearthing a dinosaur fossil and two articles. The students read through the articles about fossil expeditions and take notes. At the end, students are to create an ad for an expedition into the Gobi Desert in which they describe the skills needed to be successful for this expedition.
3. This activity is a webquest which requires students to research various pieces of evidence during different time periods and record their information in a chart. Students develop an understanding of how fossils can help paleontologists learn more about a specific time era.

4. This is an online module created by the University of California in which students navigate through different folders and investigate cladograms and develop a better understanding of how cladograms show a common ancestry.
5. Students are given pictures of various organisms (such as a pig and chicken) and they complete a Venn Diagram of similarities and difference between two organisms. Students will notice that in the beginning the embryos look similar; however, develop their distinct features later in their embryonic stage. The similarities within organisms is an evidence of evolution.
6. Students observe the embryonic development of zebrafish through video clips and afterwards independently sequence their development. Many times students are not even aware of zebra fish; however, nowadays zebrafish are used to study human diseases due to their similar organ development and function.

Unit 2: Selection and Adaptation

Unit Summary
Are Genetically Modified Organisms (GMO) safe to eat? Students construct explanations based on evidence to support fundamental understandings of natural selection and evolution. They will use ideas of genetic variation in a population to make sense of how organisms survive and reproduce, thus passing on the traits of the species. The crosscutting concepts of *patterns* and *structure and function* are called out as organizing concepts that students use to describe biological evolution. Students use the practices of *constructing explanations, obtaining, evaluating, and communicating information,* and *using mathematical and computational thinking*. Students are also expected to use these practices to demonstrate understanding of the core ideas. This unit is based on MS-LS4-4, MS-LS4-5, and MS-LS4-6.
Student Learning Objectives
Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. *[Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations]* (MS-LS4-4)
Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. *[Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as*

the technologies leading to these scientific discoveries.] **(MS-LS4-5)**
Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. *[Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [Assessment Boundary: Assessment does not include Hardy Weinberg calculations.]* **(MS-LS4-6)**

Unit Sequence	
Part A: *How can changes to the genetic code increase or decrease an individual's chances of survival?*	
Concepts	**Formative Assessments**
• Genetic variations of traits in a population increase or decrease some individuals' probability of surviving and reproducing in a specific environment. • Natural selection leads to the predominance of certain traits in a population and the suppression of others. • Natural selection may have more than one cause, and some cause-and-effect relationships within natural selection can only be described using probability.	*Students who understand the concepts can:* • Construct an explanation that includes probability statements regarding variables and proportional reasoning of how genetic variations of traits in a population increase some individuals' probability surviving and reproducing in a specific environment. • Use probability to describe some cause-and-effect relationships that can be used to explain why some individuals survive and reproduce in a specific environment.

Unit Sequence	
Part B: *How can the environment effect natural selection?*	
Concepts	**Formative Assessments**
• Natural selection, which over generations leads to adaptations, is one important process through which species change over time in response to changes in environmental conditions. • The distribution of traits in a population changes. • Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. • Natural selection may have more than one cause, and some cause-	*Students who understand the concepts can:* • Explain some causes of natural selection and the effect it has on the increase or decrease of specific traits in populations over time. • Use mathematical representations to support conclusions about how natural selection may lead to increases and decreases of genetic traits in populations over time.

and-effect relationships in natural selection can only be described using probability. • Mathematical representations can be used to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.	

Unit Sequence	
Part C: *Are Genetically Modified Organisms (GMO) safe to eat?*	
Concepts	**Formative Assessments**
• In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. • In artificial selection, humans choose desirable, genetically determined traits in to pass on to offspring. • Phenomena, such as genetic outcomes in artificial selection, may have more than one cause, and some cause-and-effect relationships in systems can only be described using probability. • Technologies have changed the way humans influence the inheritance of desired traits in organisms. • Engineering advances have led to important discoveries in the field of selective breeding. • Engineering advances in the field of selective breeding have led to the development of entire industries and engineered systems. • Scientific discoveries have led to the development of entire industries and engineered systems.	*Students who understand the concepts can:* • Gather, read, and synthesize information about technologies that have changed the way humans influence the inheritance of desired traits in organisms (artificial selection) from multiple appropriate sources. • Describe how information from publications about technologies and methods that have changed the way humans influence the inheritance of desired traits in organisms (artificial selection) used are supported or not supported by evidence. • • Assess the credibility, accuracy, and possible bias of publications and they methods they used when gathering information about technologies that have changed the way humans influence the inheritance of desired traits in organisms (artificial selection).

Connections to Other Units
Grade 6: Unit 3: Interdependent Relationships in Ecosystems • Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. • Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. **Grade 7, Unit 6: Inheritance and Variation of Traits** • Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. • Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. • In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. • In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism. Grade 7, Unit 8: Earth Systems • The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.

Appendix A: NGSS and Foundations for the Unit
Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. *[Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations]* **(MS-LS4-4)**
Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. *[Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.]* **(MS-LS4-5)**

Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. *[Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [Assessment Boundary: Assessment does not include Hardy Weinberg calculations.]* **(MS-LS4-6)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions • Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena. (MS-LS4-4) **Obtaining, Evaluating, and Communicating Information** • Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-LS4-5) **Using Mathematics and Computational Thinking** • Use mathematical representations to support scientific conclusions and design solutions. (MS-LS4-6)	**LS4.B: Natural Selection** • Natural selection leads to the predominance of certain traits in a population, and the suppression of others. (MS-LS4-4) • In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. (MS-LS4-5) **LS4.C: Adaptation** • Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. (MS-LS4-6)	**Cause and Effect** • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS4-4),(MS-LS4-5),(MS-LS4-6) - - - - - - - - - - - - - - - - ***Connections to Engineering, Technology, and Applications of Science*** **Interdependence of Science, Engineering, and Technology** • Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-LS4-5) - - - - - - - - - - - - - - - - ***Connections to Nature of Science*** **Science Addresses Questions About the Natural and Material World** • Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (MS-

		LS4-5)

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (MS-LS4-4),(MS-LS4-5) **RST.6-8.1** Compare and contrast the information gained from experiments, simulations, videos, or multimedia sources with that gained from reading a text on the same topic. (MS-LS4-4) **RST.6-8.9** Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (MS-LS4-4) **WHST.6-8.2** Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (MS-LS4-5) **WHST.6-8.8** Draw evidence from informational texts to support analysis, reflection, and research. (MS-LS4-4) **WHST.6-8.9** Engage effectively in a range of collaborative discussions (one-on-one, in groups, teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly. (MS-LS4-4) **SL.8.1** Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (MS-LS4-4) **SL.8.4**	Model with mathematics. (MS-LS4-6) **MP.4** Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-LS4-4),(MS-LS4-6) **6.RP.A.1** Summarize numerical data sets in relation to their context. (MS-LS4-4),(MS-LS4-6) **6.SP.B.5** Recognize and represent proportional relationships between quantities. (MS-LS4-4),(MS-LS4-6) **7.RP.A.2**

Unit 2: Selection and Adaptation (20 days)			
This unit is based on:	SLO	Inquiry Menu	Quick Links
MS-LS4-4	Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.	1. Battle of the Beaks 2. 99.99% Antibacterial Products And Natural Selection	1. http://www.ucmp.berkeley.edu/education/lessons/birdbeaks/birdbeaks.html 2. http://digital.nsta.org/article/99.99%25+ANTIBACTERIAL+PRODUCTS+AND+NATURAL+SELECTION/1562472/184198/article.html
MS-LS4-5	Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.	3. Peppered Moths 4. Introduction of PBL: Is It the End of Humanity?	3. https://api.betterlesson.com/mtp/lesson/637464/print Link from above website: http://peppermoths.weebly.com/ 4. http://betterlesson.com/lesson/635476/introduction-of-pbl-is-it-the-end-of-humanity
MS-LS4-6	Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.	5. Pocket Mouse Example - Natural Selection 6. Evolution by Natural Selection	5. https://api.betterlesson.com/mtp/lesson/636021/print Video to go with above lesson: http://www.hhmi.org/biointeractive/making-fittest-natural-selection-and-adaptation 6. http://serendip.brynmawr.edu/sci_edu/waldron/pdf/NaturalSelectionTeachPrep.pdf

1. Students are asked to select one of the following items and have a seat: scissors, spoons, tweezers, and binder clip. Afterwards, the students are told that the item they selected represents their *beak* and they will be required to hunt for *food*. The teacher will place various items that represent food, such as paper clips, rubber bands, toothpicks, and uncooked macaroni. The student will then select the *food* which is best for his/her *beak*.
    a. This can lead to further discussions of *adaptation, extinction* and the *food chain*
2. Students are given a toothpick (represents hand sanitizer) and a plate full of Skittles and mini marshmallows (which represent bacteria). They are to *catch* as much bacteria with their toothpick in 7 seconds. The marshmallows will be easier to catch and the Skittles are harder showing that hand sanitizer kills 99.9% of the bacteria (marshmallows) and the .01% that it can't kill, is drug resistant bacteria. This illustrates to students that the *fittest* bacteria survived and multiplied in number while bacteria that was easy to kill is erased.
3. Students participate in an online simulation in which they tried to catch peppered moths in various backgrounds. During the industrial revolution the factories produced smog which resulted in *industrial melanism*. The white peppered moths were easier to spot on the darker buildings; thereby making them easier preys. This resulted in a shift in the peppered moth population.
4. Students are told that the world is going to end and there are only three ecosystems remaining: salt water oceans, expansive deserts and vast arctic regions. Their job is to research each ecosystem and identify what traits are favorable in their environments. Then the students will explain how humans can use genetic technology to ensure humanity survives.
5. This lesson comes with a brief video clip to introduce students to the variation of pocket mouse. The students are given sheets of paper with mouse drawings on them (The background color varies and some mice are more visible) The students count the mice, record their data on a chart, and later graph it to show an increase/decrease in a specific variation.
6. This activity requires teachers to setup two different environments (3 yards of faux fur and fleece) and lay out various colored pompoms. The students use a fork and spoon to put the pompoms in their cups which represents their stomach. The simulation continues throughout the period and students observe the population change across 3 generations. This requires students to obtain data and calculate the percent change of the population.

Unit 3: Stability and Change on Earth

Unit Summary
Why aren't minerals and groundwater distributed evenly across the world?
Students construct an understanding of the ways that human activities affect Earth's systems. Students use practices to understand the significant and complex issues surrounding human uses of land, energy, mineral, and water resources and the resulting impacts on the development of these resources. Students also understand that the distribution of these resources is uneven due to past and current geosciences processes or removal by humans. The crosscutting concepts of *patterns, cause and effect*, and *stability and change* are called out as organizing concepts for these disciplinary core ideas. In this unit of study students are expected to demonstrate proficiency in *asking questions, analyzing and interpreting data, constructing*

explanations, and designing solutions. Students are also expected to use these practices to demonstrate understanding of the core ideas. This unit is based on MS-ESS3-1, MS-ESS3-2, MS-ESS3-4, and MS-ESS3-5.
Student Learning Objectives
Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. *[Clarification Statement: Emphasis is on how these resources are limited and typically nonrenewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).]* **(MS-ESS3-1)**
Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. *[Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).]* **(MS-ESS3-2)**
Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. *[Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]* **(MS-ESS3-4)**
Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. *[Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]* **(MS-ESS3-5)**

Unit Sequence	
Part A: *Why aren't minerals and groundwater distributed evenly across the world?*	
Concepts	**Formative Assessments**
• Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. • All human activities draw on Earth's land, ocean, atmosphere, and biosphere resources and have both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. • Minerals, fresh water, and biosphere resources are distributed unevenly around the planet as a result of past geologic processes. • Cause-and-effect relationships may be used to explain how uneven distributions of Earth's mineral, energy, and groundwater resources have resulted from past and current geosciences processes. • Resources that are unevenly distributed as a result of past processes include but are not limited to petroleum, metal ores, and soil. • Mineral, fresh water, ocean, biosphere, and atmosphere resources are limited, and many are not renewable or replaceable over human lifetimes. • The distribution of some of Earth's land, ocean, atmosphere, and biosphere resources are changing significantly due to removal by humans.	*Students who understand the concepts can:* • Construct a scientific explanation based on valid and reliable evidence of how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geosciences processes. • Obtain evidence from sources, which must include the student's own experiments. • Construct a scientific explanation based on the assumption that theories and laws that describe the current geosciences process operates today as they did in the past and will continue to do so in the future.

Unit Sequence	
Part B: *How can we predict and prepare for natural disasters?*	
Concepts	**Formative Assessments**
• Natural hazards can be the result of interior processes, surface processes, or severe weather events. • Some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but	*Students who understand the concepts can:* • Analyze and interpret data on natural hazards to determine similarities and differences and to distinguish between correlation

others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. • Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events. • Data on natural hazards can be used to forecast future catastrophic events and inform the development of technologies to mitigate their effects. • Data on natural hazards can include the locations, magnitudes, and frequencies of the natural hazards. • Graphs, charts, and images can be used to identify patterns of natural hazards in a region. • Graphs, charts, and images can be used to understand patterns of geologic forces that can help forecast the locations and likelihoods of future events. • Technologies that can be used to mitigate the effects of natural hazards can be global or local. • Technologies used to mitigate the effects of natural hazards vary from region to region and over time.	and causation.

Unit Sequence	
Part C: *How might we treat resources if we thought about the Earth as a spaceship on an extended survey of the solar system? (How would astronauts manage their resources?)*	
Concepts	**Formative Assessments**
• All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. • Increases in human population and per-capita consumption of natural resources impact Earth's systems. • Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.	*Students who understand the concepts can:* • Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

• Cause and effect relationships may be used to predict how increases in human population and per-capita consumption of natural resources impact Earth's systems. • The consequences of increases in human populations and consumption of natural resources are described by science. • Science does not make the decisions for the actions society takes. • Scientific knowledge can describe the consequences of human population and per-capita consumption of natural resources impact Earth's systems but does not necessarily prescribe the decisions that society takes.	

Unit Sequence

Part D: *How can basic chemistry be used to explain the mechanisms that control the global temperature the atmosphere?*

Concepts	Formative Assessments
• Stability in Earth's surface temperature might be disturbed either by sudden events or gradual changes that accumulate over time. • Human activities and natural processes are examples of factors that have caused the rise in global temperatures over the past century. • Human activities play a major role in causing the rise in global temperatures. • Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). • Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior, and on applying that knowledge wisely in decisions and activities. • Evidence that some factors have caused the rise in global temperature over the last century can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human	*Students who understand the concepts can:* • Ask questions to identify and clarify a variety of evidence for an argument about the factors that have caused the rise in global temperatures over the past century. • Ask questions to clarify human activities and natural processes that are major factors in the current rise in Earth's mean surface temperature.

activities.	

Connections to Other Units

Grade 7 Unit 1: Structure and Properties of Matter

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

Grade 7 Unit 2: Interactions of Matter

- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

Grade 7 Unit 3: Chemical Reactions

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.

Grade 8 Unit 5: Forms of Energy

- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

Grade 6 Unit 7: Weather and Climate

- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.
- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

- Because these patterns are so complex, weather can only be predicted probabilistically.

Appendix A: NGSS and Foundations for the Unit

Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. *[Clarification Statement: Emphasis is on how these resources are limited and typically nonrenewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).]* **(MS-ESS3-1)**

Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. *[Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).]* **(MS-ESS3-2)**

Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. *[Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]* **(MS-ESS3-4)**

Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. *[Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]* **(MS-ESS3-5)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts

Constructing Explanations and Designing Solutions • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (MS-ESS3-1) **Engaging in Argument from Evidence** • Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-ESS3-4)	**ESS3.A: Natural Resources** • Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. (MS-ESS3-1) **ESS3.B: Natural Hazards** • Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS-ESS3-2) **ESS3.C: Human Impacts on Earth Systems** • Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-4) **ESS3.D: Global Climate Change** • Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of	**Patterns** • Graphs, charts, and images can be used to identify patterns in data. (MS-ESS3-2) **Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS3-1),(MS-ESS3-4) **Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. (MS-ESS3-5) - - - - - - - - - - - - - - - - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ESS3-1),(MS-ESS3-4) • The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-ESS3-2) - - - - - - - - - - - - - - - -

	human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)	***Connections to Nature of Science*** **Science Addresses Questions About the Natural and Material World** • Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (MS-ESS3-4)

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts. (MS-ESS3-1),(MS-ESS3-2) **RST.6-8.1** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ESS3-2) **RST.6-8.7** Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (MS-ESS3-1) **WHST.6-8.2** Draw evidence from informational texts to support analysis, reflection, and research. (MS-ESS3-1) **WHST.6-8.9**	Reason abstractly and quantitatively. (MS-ESS3-2) **MP.2** Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. (MS-ESS3-1),(MS-ESS3-2) **6.EE.B.6** Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (MS-ESS3-1),(MS-ESS3-2) **7.EE.B.4**

Unit 3: Stability and Change on Earth (30 days)			
This unit is based on:	**SLO**	**Inquiry Menu**	**Quick Links**
MS-ESS3-1	Construct a scientific explanation	1. What are Fossil Fuels?	1. http://betterlesson.com/lesson/638641

	based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.	2. Blame it on the Carbon	/what-are-fossil-fuels 2. http://betterlesson.com/lesson/638033/blame-it-on-the-carbon
MS-ESS3-2	Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.	3. Earthquake Hazards 4. A Man Made Disaster	3. http://betterlesson.com/lesson/629624/earthquake-hazards 4. http://betterlesson.com/lesson/634718/a-man-made-disaster
MS-ESS3-4	Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.	5. Design Your Society 6. Blame it on the Carbon 7. The Story of Stuff	5. http://betterlesson.com/lesson/644797/design-your-society 6. http://betterlesson.com/lesson/638033/blame-it-on-the-carbon 7. http://betterlesson.com/lesson/631899/the-story-of-stuff
MS-ESS3-5	Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.	8. NASA Climate Change Modules (3 offered) 9. What is Climate? and what causes it to change? 10. Earth's Changing Climate	8. http://climate.nasa.gov/resources/education/pbs_modules/ 9. http://betterlesson.com/lesson/635264/what-is-climate-and-what-causes-it-to-change 10. http://betterlesson.com/lesson/640758/earth-s-changing-climate

1. What are Fossil Fuels?-students will explain how fossil fuels were formed and how they impact climate change. They discuss why fossil fuels are important and introduces the role of fossil fuels in creating new technologies. Students create conceptual models of the formation of fossil fuels . After reading an article students are to support how fossil fuels are essential to our economy and include a citation
2. Blame it on the Carbon – as students describe how the carbon cycle contributes to the condition of our environment, they gain a better understanding of the cause and effect of human activities on the Earth's systems. Students will also calculate the carbon footprint of themselves as individuals and of their households, the class will compare results in order to calculate an average carbon foot print

3. Earthquake Hazards-Students will identify major seismic hazards and evaluate the effectiveness of various safety measures using an online interface. The lesson starts with a brief text excerpt on earthquake hazards and emergency preparedness. They read this in partners and answer some basic analysis questions, and then launch into a computer-based lesson asking them to prepare safety information for before, during, and after an earthquake happens. Finally, there's a brief writing assignment asking them to prioritize some of their selected safety information and give needed rationale for it
4. A Man Made Disaster-Students will read and annotate non fiction text and will examine a disaster to determine what could happen if there were better ways to prevent and respond to it.
5. Design Your Society – students will apply newly acquired knowledge to develop plans for a new society on Earth. End goals of activity: Design a resilient, self-sustaining society that can withstand the challenges that will be faced by the new hostile environment found on Earth. Points to consider are: Housing Structures/Safety, Energy, Transportation, Waste Management, and Food Production.

6. Blame it on the Carbon – as students describe how the carbon cycle contributes to the condition of our environment, they gain a better understanding of the cause and effect of human activities on the Earth's systems. Students will also calculate the carbon footprint of themselves as individuals and of their households, the class will compare results in order to calculate an average carbon foot print
7. The Story of Stuff – the way we consume and dispose of material goods reflect our culture and way of life. The culture of America is wasteful and we must consider ways to reduce our consumption of material goods in order to sustain life on our planet.
8. NASA Climate Change Modules (3 offered) – Module 1: Introduction to Earth's Dynamically Changing Climate - Examine evidence of climate change from different parts of the Earth's system and consider what it means to live on a planet with a dynamically changing climate. Module 2: Impacts of Artic Warming - Examine the evidence for changes in ice cover at the Arctic and explore why climate changes at the poles are so important to the rest of the climate system. Module 3: Coastal Consequences of Sea Level Rise - Learn how sea level rise will have increasingly serious consequences for human health and life quality.
9. What is Climate? and what causes it to change? – This is an opening activity, used to assess prior knowledge, use this lesson to find out what your students initial ideas are on climate and climarte change.
10. Earth's Changing Climate – Remember the old adage, "a picture is worth a thousand words." Our Earth is in a period of warming but how warm will the planet get? Take a look at these models and data to make perdictions about the future.

Unit 4: Human Impacts on Earth Systems and Global Climate Change

Unit Summary
How do we monitor the health of the environment (our life support system)?

Is it possible to predict and protect ourselves from natural hazards?

In this unit of study, students analyze and interpret data and design solutions to build on their understanding of the ways that human activities affect Earth's systems. The emphasis of this unit is the significant and complex issues surrounding human uses of land, energy, mineral, and water resources and the resulting impacts of these uses. The crosscutting concepts of *cause and effect* and *the influence of science, engineering, and technology on society and the natural world* are called out as organizing concepts for these disciplinary core ideas.

Building on Unit 3, students define a problem by precisely specifying criteria and constraints for solutions as well as potential impacts on society and the natural environment; systematically evaluate alternative solutions; analyze data from tests of different solutions; combining the best ideas into an improved solution; and develop and iteratively test and improve their model to reach an optimal solution. In this unit of study students are expected to demonstrate proficiency in *analyzing and interpreting data* and *designing solutions.* Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-ESS3-3, MS-ETS1-1, MS-ETS1-2, and MS-ETS1-3.

Student Learning Objectives
Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. *[Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating) solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]* **(MS-ESS3-3)**
Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. (MS-ETS1-1)
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. (MS-ETS1-2)
Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. (MS-ETS1-3)

Unit Sequence

Part A: *How do we monitor the health of the environment (our life support system)?*

Concepts	Formative Assessments
• Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. • Changes to Earth's environments can have different impacts (negative and positive) for different living things. • Typically as human populations and per capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise. • Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. • The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.	*Students who understand the concepts can:* • Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Connections to Other Units

Grade 6, Unit 2: Matter and Energy in Organisms and Ecosystems

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
- Growth of organisms and population increases are limited by access to resources.
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.

Grade 6, Unit 5: Types of Interactions

- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.
- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.
- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

Appendix A: NGSS and Foundations for the Unit

Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. *[Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating) solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]* **(MS-ESS3-3)**

Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. (MS-ETS1-1)

Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. (MS-ETS1-2)

Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. (MS-ETS1-3)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural	**ESS3.C: Human Impacts on Earth Systems** • Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.	**Cause and Effect** • Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. (MS-ESS3-3) - - - - - - - - - - - - - - - -

world operate today as they did in the past and will continue to do so in the future. (MS-ESS3-1) • Apply scientific principles to design an object, tool, process or system. (MS-ESS3-3) **Asking Questions and Defining Problems** • Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1) **Engaging in Argument from Evidence** • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2) **Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3)	(MS-ESS3-3) • Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3),(MS-ESS3-4) **ETS1.A: Defining and Delimiting Engineering Problems** • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1) **ETS1.B: Developing Possible Solutions** A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3) • Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3) • Models of all kinds are important for testing solutions. (MS-ETS1-4)	- - - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-ESS3-3) **Influence of Science, Engineering, and Technology on Society and the Natural World** • All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ETS1-1) • The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts. (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3) **RST.6-8.1** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ESS3-3),(MS-ETS1-3) **RST.6-8.7** Compare and contrast the information gained from experiments, simulations, videos, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-2),(MS-ETS1-3) **RST.6-8.9** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-ETS1-2) **WHST.6-8.7** Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (MS-ESS3-3),(MS-ETS1-1) **WHST.6-8.8** Draw evidence from informational texts to support analysis, reflection, and research. (MS-ETS1-2) **WHST.6-8.9** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-ETS1-4) **SL.8.5**	Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. (MS-ESS3-3) **6.EE.B.6** Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (MS-ESS3-3) **7.EE.B.4** Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-ESS3-3) **6.RP.A.1** Recognize and represent proportional relationships between quantities. (MS-ESS3-3) **7.RP.A.2** Reason abstractly and quantitatively. (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3) **MP.2** Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3) **7.EE.3**

Unit 4:Earth and Human Activity (25 days)			
This unit is based on:	**SLO**	**Inquiry Menu**	**Quick Links**
MS-ESS3-3	Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	1. Carbon Sinks 2. Climate change and the greenhouse effect 3. Where does the waste go?	1. http://betterlesson.com/lesson/636043/carbon-sinks-modeling-the-future 2. http://betterlesson.com/lesson/631905/climate-change-and-the-greenhouse-effect 3. http://betterlesson.com/lesson/631904/where-the-waste-goes
MS-ETS1-1	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	4. Renewable and non-renewable energy sources 5. Designing an eco-friendly building (part 2)	4. http://betterlesson.com/lesson/629913/renewable-and-non-renewable-energy-sources 5. http://betterlesson.com/lesson/636976/designing-an-eco-friendly-building-part-2
MS-ETS1-2	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	6. Designing an eco-friendly building (part 4) 7. Designing an eco-friendly building (part 1)	6. http://betterlesson.com/lesson/637438/designing-an-eco-friendly-building-part-4 7. http://betterlesson.com/lesson/633426/designing-an-eco-friendly-building-part-1
MS-ETS1-3	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	8. Designing an eco-friendly building (part 3)	8. http://betterlesson.com/lesson/637437/designing-an-eco-friendly-building-part-3

1. In this activity, MS_ESS3-3 students develop and run scenarios for future human emissions and future carbon sinks in the oceans and on the land. Running an applet allows them to simulate the impact on atmospheric CO2 and global mean temperature. The applet is part of the Carbon and Climate website at the University of Wisconsin, Madison.
2. Students will explain the relationship between the carbon cycle, the formation of greenhouse gases, and the effect on climate. After recording temperatures for 10 cycles, students graph their data in their lab guide. We discuss as a class, identifying patterns or trends, pointing out outliers and discussing possible reasons to explain their appearance and their significance to the investigation. This activity goes along with MS-ESS3-3
3. In this lesson students investigate their own trash consumption and become aware of how the disposal of non-biodegradable waste impacts the environment. This activity can go along with MS-ESS3-3
4. Using their design ideas from the research of eco-friendly components, students will create a model of their eco-friendly building. This goes along with MS-ETS1-2
5. This activity goes with MS-ETS1-1. Students will investigate what is the best energy source and can renewables be the future?
6. This lesson allows students to research eco-friendly components as students determine the best solution an authentic design problem. This activity can go along with MS-ETS1-1.
7. This lesson helps students understand why eco-friendly architecture is an important design problem goes along with MS-ESS3-3, MS-ETS1-1, MS-ETS1-2 and MS-ETS1-2.
8. In this lesson, using their research students will begin to design a floor plan, thinking about the best way to solve the design problem. This activity can go along with MS-ETS1-1, MS-ETS1-2, MS-ETS1-3

Unit 5: Relationships Among Forms of Energy

Unit Summary
How can physics explain sports?
In this unit, students use the practices of *analyzing and interpreting data, developing and using models*, and *engaging in argument from evidence* to make sense of relationship between energy and forces. Students develop their understanding of important qualitative ideas about the conservation of energy. Students understand that objects that are moving have kinetic energy and that objects may also contain stored (potential) energy, depending on their relative positions. Students also understand the difference between energy and temperature, and the relationship between forces and energy. The crosscutting concepts of *scale, proportion, and quantity, systems and system models*, and *energy and matter* are called out as organizing concepts for these disciplinary core ideas. Students use the practices of *analyzing and interpreting data, developing and using models*, and *engaging in*

argument from evidence. Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-PS3-1, MS-PS3-2, and MS-PS3-5.

Student Learning Objectives

Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. *[Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]* **(MS-PS3-1)**

Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. *[Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.]* **(MS-PS3-2)**

Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. *[Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [Assessment Boundary: Assessment does not include calculations of energy.]* **(MS-PS3-5)**

Unit Sequence

Part A: *Is it better to have an aluminum (baseball/softball) bat or a wooden bat?*

Concepts	Formative Assessments
• Kinetic energy is related to the mass of an object and to the speed of an object. • Kinetic energy has a relationship to mass separate from its relationship to speed. • Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of the	*Students who understand the concepts can:* • Construct and interpret graphical displays of data to identify linear and nonlinear relationships of kinetic energy to the mass of an object and to the speed of an object.

object's speed. • Proportional relationships among different types of quantities provide information about the magnitude of properties and processes.	

Unit Sequence

Part B: *What would give you a better chance of winning a bowling match, using a basketball that you can roll really fast, or a bowling ball that you can only roll slowly?*

Concepts	Formative Assessments
• When the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. • A system of objects may contain stored (potential) energy, depending on the objects' relative positions. • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the objects. • Models that could include representations, diagrams, pictures, and written descriptions of systems can be used to represent systems and their interactions, such as inputs, processes, and outputs, and energy and matter flows within systems.	*Students who understand the concepts can:* • Develop a model to describe what happens to the amount of potential energy stored in the system when the arrangement of objects interacting at a distance changes • Use models to represent systems and their interactions, such as inputs, processes, and outputs, and energy and matter flows within systems. Models could include representations, diagrams, pictures, and written descriptions.

Unit Sequence

Part C: *Who can design the best roller coaster?*

Concepts	Formative Assessments
• When the kinetic energy of an object changes, energy is transferred to or from the object. • When the motion energy of an object changes, there is inevitably some other change in energy at the same time. • Kinetic energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).	*Students who understand the concepts can:* • Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. • Conduct an inventory or other representation of the energy before

	and after the transfer in the form of temperature changes or motion of an object. Do not include calculations of energy.

Appendix A: NGSS and Foundations for the Unit
Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. *[Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]* **(MS-PS3-1)**
Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. *[Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.]* **(MS-PS3-2)**
Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. *[Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [Assessment Boundary: Assessment does not include calculations of energy.]* **(MS-PS3-5)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Develop a model to describe unobservable mechanisms. (MS-PS3-2) **Analyzing and Interpreting Data** • Construct and interpret graphical displays of data to identify linear and nonlinear relationships. (MS-PS3-1)	**PS3.A: Definitions of Energy** • Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (MS-PS3-1) • A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2) **PS3.B: Conservation of Energy and Energy**	**Scale, Proportion, and Quantity** • Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. (MS-PS3-1) **Systems and System Models** • Models can be used to represent systems and their interactions – such as inputs,

Engaging in Argument from Evidence • Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon. (MS-PS3-5) - ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations (MS-PS3-5)	**Transfer** • When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5) **PS3.C: Relationship Between Energy and Forces** • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2)	processes, and outputs – and energy and matter flows within systems. (MS-PS3-2) **Energy and Matter** • Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-PS3-5)

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. *(MS-PS3-1),(MS-PS3-5)* **RST.6-8.1** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS3-1) **RST.6-8.7** Write arguments focused on discipline content. *(MS-PS3-5)* **WHST.6-8.1** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-PS3-3) **WHST.6-8.7** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. *(MS-PS3-*	Reason abstractly and quantitatively. (MS-PS3-1),(MS-PS3-5) **MP.2** Understand the concept of ratio and use ratio language to describe a ratio relationship between two quantities. (MS-PS3-1),(MS-PS3-5) **6.RP.A.1** Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0, and use rate language in the context of a ratio relationship. (MS-PS3-1) **6.RP.A.2** Recognize and represent proportional relationships between quantities. (MS-PS3-1),(MS-PS3-5) **7.RP.A.2** Know and apply the properties of integer exponents to generate equivalent numerical expressions. (MS-PS3-1) **8.EE.A.1** Use square root and cube root symbols to represent solutions to equations of the form $x^2 = p$ and $x^3 = p$, where p is a positive rational

2) **SL.8.5**	number. Evaluate square roots of small perfect squares and cube roots of small perfect cubes. Know that √2 is irrational. (MS-PS3-1) **8.EE.A.2** Interpret the equation y = mx + b as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. (MS-PS3-1),(MS-PS3-5) **8.F.A.3**

Unit 5: Relationships among Forms of Energy (20 days)

This unit is based on:	SLO	Inquiry Menu	Quick Links
MS-PS3-1	Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.	1. Bowling for Science 2. Skate park simulation 3. Ramp Activity – part 1	1. Attachment 2. http://betterlesson.com/lesson/640019/exploring-the-relationship-between-potential-kinetic-energy 3. Attachment
MS-PS3-2	Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system	4. Roller coaster simulator 5. Ramp activity – part 2 6. Marble drop activity 7. Rubber band cannons	4. http://www.physicsclassroom.com/Physics-Interactives/Work-and-Energy/Roller-Coaster-Model/Roller-Coaster-Model-Interactive 5. Attachment 6. http://betterlesson.com/lesson/633998/kinetic-and-potential-energy-lab-rotation 7. http://betterlesson.com/lesson/633996/rubber-band-cannon-lab
MS-PS3-5	Construct, use, and present arguments to support the claim that	8. Rube Goldberg Machines	8. Attachment

	when the kinetic energy of an object changes, energy is transferred to or from the object.	9. Transformation demonstration	9. Attachment

1. This activity will demonstrate that the kinetic energy an object possesses is determined by its mass and the speed with which it's moving. It will show that kinetic energy has a relationship to mass separate from its relationship to speed, by conducting the activity in two parts – one with speed constant and one
2. This simulation allows the user to change the mass of the skater and records the change to the amount of kinetic energy, potential energy, and speed of the skater. Student worksheets are provided. (Can be done in a computer lab or as a demo on the smartboard)
3. This activity will allow students to predict how mass impacts kinetic energy. Students will roll balls of different masses down a ramp, and will calculate the amount of kinetic energy that each ball possesses. Students can collect the data and represent it graphically.
4. This simulation allows students to design a roller coaster with various heights, loops, etc., and determine the effect each has on both potential and kinetic energy
5. Students will use ramps of varying heights to collect evidence to support the claim that potential energy is dependent upon height.
6. Students will drop marbles from various heights into flour or clay, and measure the "crater" is produces to determine the relationship between height and the amount of potential energy.
7. Students will explore elastic potential energy through this investigation.
8. Students will a Rube Goldberg machine to investigate how energy transfers from one object to or from another object.
9. Students will observe various energy transformations, and will predict and identify the types of energy involved

Unit 6: Thermal Energy

Unit Summary

How can a standard thermometer be used to tell you how particles are behaving?

In this unit, students *ask questions, plan and carry out investigations, engage in argument from evidence, analyze and interpret data, construct explanations, define problems and design solutions* as they make sense of the difference between energy and temperature. They use the practices to make sense of how the total change of energy in any system is always equal to the total energy transferred into or out of the system. The crosscutting concepts of *energy and matter, scale, proportion, and quantity*, and *influence of science, engineering, and technology on society and the natural world* are the organizing concepts for these disciplinary core ideas. Students ask *questions, plan and carry out investigations, engage in argument from evidence, analyze and interpret data, construct explanations, define problems and design solutions.* Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-PS3-3, MS-PS3-4, MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, and MS-ETS1-4.
Student Learning Objectives
Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. *[Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]* **(MS-PS3-3)**
Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. *[Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]* **(MS-PS3-4)**
Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. (MS-ETS1-1)
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. (MS-ETS1-2)
Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. (MS-ETS1-3)
Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. (MS-ETS1-4)

Unit Sequence	
Part A: *How can a standard thermometer be used to tell you how particles are behaving?*	
Concepts	**Formative Assessments**
• There are relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of	*Students who understand the concepts can:*

particles as measured by the temperature of the sample. • Temperature is a measure of the average kinetic energy of particles of matter. • The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. • The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. • Proportional relationships among the amount of energy transferred, the mass, and the change in the average kinetic energy of particles as measured by temperature of the sample provide information about the magnitude of properties and processes.	• Individually and collaboratively plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of particles as measured by the temperature of the sample. • As part of a planned investigation, identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. • Make logical and conceptual connections between evidence and explanations.

Unit Sequence

Part B: You are an engineer working for NASA. In preparation for a manned space mission to the Moon, you are tasked with designing, constructing, and testing a device that will keep a hot beverage hot for the longest period of time. It costs approximately $10,000 per pound to take payload into orbit so the devise must be lightweight and compact. The lack of atmosphere on the Moon produces temperature extremes that range from -157 degrees C in the dark to +121 degrees C in the light. Your devise must operate on either side of the Moon (https://spaceflightsystems.grc.nasa.gov/education/rocket/moon.html).

Concepts	**Formative Assessments**
• Temperature is a measure of the average kinetic energy of particles of matter. • The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. • Energy is spontaneously transferred out of hotter regions or objects and into colder ones. • The transfer of energy can be tracked as energy flows through a designed or natural system. • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be	*Students who understand the concepts can:* • Apply scientific ideas or principles to design, construct, and test a design of a device that either minimizes or maximizes thermal energy transfer. • Determine design criteria and constraints for a device that either minimizes or maximizes thermal energy transfer. • Test design solutions and modify them on the basis of the test results in order to improve them. • Use a systematic process for evaluating solutions with respect to how

successful. • Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. • A solution needs to be tested and then modified on the basis of the test results in order to improve it. • There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.	well they meet criteria and constraints.

Connections to Other Units

Grade 6, Unit 4: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

Grade 6, Unit 7: Weather and Climate

- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.
- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- Global movements of water and its changes in form are propelled by sunlight and gravity.
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.
- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- Because these patterns are so complex, weather can only be predicted probabilistically.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it

through ocean currents.

Grade 7, Unit 1: Structure and Properties of Matter

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

Grade 7, Unit 2: Interactions of Matter

- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

Grade 7, Unit 3: Chemical Reactions

- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Grade 7, Unit 8: Earth Systems

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

Grade 8, Unit 3: Stability and Change on Earth

- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Appendix A: NGSS and Foundations for the Unit

Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. *[Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]* **(MS-PS3-3)**

Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. *[Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]* **(MS-PS3-4)**

Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. (MS-ETS1-1)

Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. (MS-ETS1-2)

Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. (MS-ETS1-3)

Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. (MS-ETS1-4)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to	**PS3.A: Definitions of Energy** • Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (MS-PS3-3),(MS-PS3-4)	**Scale, Proportion, and Quantity** • Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. (MS-PS3-4)

support a claim. (MS-PS3-4) **Constructing Explanations and Designing Solutions** • Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-PS3-3) **Asking Questions and Defining Problems** • Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1) **Developing and Using Models** • Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4) **Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3) **Engaging in Argument from Evidence** • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2)	**PS3.B: Conservation of Energy and Energy Transfer** • The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (MS-PS3-4) • Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3) **ETS1.A: Defining and Delimiting Engineering Problems** • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1) **ETS1.B: Developing Possible Solutions** • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3) • Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3) • Models of all kinds are important for testing solutions. (MS-ETS1-4) **ETS1.C: Optimizing the Design Solution**	**Energy and Matter** • The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS3-3) **Influence of Science, Engineering, and Technology on Society and the Natural World** • All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ETS1-1) • The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

	• Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (MS-ETS1-3) • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)	

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts. (MS-PS3-5),MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3) **RST.6-8.1** Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (MS-PS3-3),(MS-PS3-4) **RST.6-8.3** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS3-3),(MS-PS3-4),(MS-ETS1-3) **RST.6-8.7** Compare and contrast the information gained from experiments, simulations, videos, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-2),(MS-ETS1-3) **RST.6-8.9** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-ETS1-2) **WHST.6-8.7**	Reason abstractly and quantitatively. (MS-PS3-4),(MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3),(MS-ETS1-4) **MP.2** Summarize numerical data sets in relation to their context. (MS-PS3-4) **6.SP.B.5** Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3) **7.EE.3** Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy. (MS-ETS1-4) **7.SP**

Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (MS-ETS1-1) **WHST.6-8.8** Draw evidence from informational texts to support analysis, reflection, and research. (MS-ETS1-2) **WHST.6-8.9** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-ETS1-4) **SL.8.5**	

Unit 6: Thermal Energy (30 days)			
This unit is based on:	**SLO**	**Inquiry Menu**	**Quick Links**
MS-PS3-3	Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer	1. Build a better thermos activity 2. Designing Thermal protection systems activity	1. http://betterlesson.com/lesson/628050/build-a-thermos 2. http://betterlesson.com/lesson/634000/thermal-protection-systems-day-1
MS-PS3-4	Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.	3. Heating sand and water activity 4. Activity: Impact of ice on water temperature	3. Refer to "Weather and climate" book activity on page 40 4. See description below
MS-ETS1-1	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	5. Design a hot air balloon (links with MS-PS3 -4 and MS-ETS1 -3 and MS-ETS1 -4) 6. Solar Smores (links with MS-PS3 -3)	5. http://betterlesson.com/lesson/640487/hot-air-balloons 6. http://betterlesson.com/lesson/640858/exploring-radiation-solar-s-mores
MS-ETS1-2	Evaluate competing design solutions using a systematic process to	1. Thermos competition	

	determine how well they meet the criteria and constraints of the problem.		
MS-ETS1-3	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	5. Balloon activity	
MS-ETS1-4	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	5. Balloon activity	

1. In this activity students will apply scientific principles to design construct and test a device that minimizes or maximizes thermal energy transfer
2. In this activity, students will use informational text to create design criteria for objects re-entering Earth's atmosphere.
3. Students will collect evidence to investigate the relationship among the energy transferred and the type of matter (specific heat) by recording the change in average kinetic energy in particles as measured by the temperature of the sample, as sand and water are heated. (Extension can be to use different masses of the same material)
4. Students will collect evidence to compare final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature.
5. Students will design a hot air balloon powered by birthday candles to explore the concept of convection and heat transfer.
6. Students will construct a solar powered oven, and must determine the best location to provide optimum energy transfer.

Unit 7: The Electromagnetic Spectrum

Unit Summary
How do cell phones work?   In this unit of study, students *develop and use models, use mathematical thinking,* and *obtain, evaluate, and communicate information* in order to describe and predict characteristic properties and behaviors of waves. Students also apply their understanding of waves as a means of sending digital information. The crosscutting concepts of *patterns* and *structure and function* are used as organizing concepts for these disciplinary core ideas.

Students *develop and use models, use mathematical thinking,* and *obtain, evaluate, and communicate information.* Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-PS4-1, MS-PS4-2, and MS-PS4-3.

Student Learning Objectives

Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. *[Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.]* **(MS-PS4-1)**

Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. *[Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]* **(MS-PS4-2)**

Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. *[Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.]* **(MS-PS4-3)**

Unit Sequence

Part A: *Why do surfers love physicists?*

Concepts	Formative Assessments
• A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. • Describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. • Graphs and charts can be used to identify patterns in data. • Waves can be described with both qualitative and quantitative thinking.	*Students who understand the concepts can:* • Use mathematical representations to describe and/or support scientific conclusions about how the amplitude of a wave is related to the energy in a wave. • Use mathematical representations to describe a simple model.

Unit Sequence	
Part B: *How do the light and sound system in the auditorium work?*	
Concepts	**Formative Assessments**
• When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. • The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. • A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. • Waves are reflected, absorbed, or transmitted through various materials. • A sound wave needs a medium through which it is transmitted. • Because light can travel through space, it cannot be a matter wave, like sound or water waves. • The structure of a wave can be modified to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.	*Students who understand the concepts can:* • Develop and use models to describe the movement of waves in various materials.

Unit Sequence	
Part C: *If rotary phones worked for my grandparents, why did they invent cell phones?*	
Concepts	**Formative Assessments**
• Structures can be designed to use properties of waves to serve particular functions. • Waves can be used for communication purposes. • Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information than are analog signals. • Wave-related technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations.	*Students who understand the concepts can:* • Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims that digitized signals are a more reliable way to encode and transmit information than analog signals are.

Connections to Other Units
Grade 7, Unit 5: Body Systems • Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.

Appendix A: NGSS and Foundations for the Unit		
Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. *[Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.]* **(MS-PS4-1)**		
Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. *[Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]* **(MS-PS4-2)**		
Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. *[Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.]* **(MS-PS4-3)**		
The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking • Use mathematical representations to describe and/or support scientific conclusions and design solutions. (MS-PS4-1) **Developing and Using Models**	**PS4.A: Wave Properties** • A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1) • A sound wave needs a medium through which it is transmitted. (MS-PS4-2) **PS4.B: Electromagnetic Radiation**	**Patterns** • Graphs and charts can be used to identify patterns in data. (MS-PS4-1) **Structure and Function** • Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-

• Develop and use a model to describe phenomena. (MS-PS4-2) **Obtaining, Evaluating, and Communicating Information** • Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings. (MS-PS4-3) - - - - - - - - - - - - - - - - ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS4-1)	• When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2) • The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS-PS4-2) • A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. (MS-PS4-2) • However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2) **PS4.C: Information Technologies and Instrumentation** • Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3)	2) • Structures can be designed to serve particular functions. (MS-PS4-3) - - - - - - - - - - - - - - - - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3) - - - - - - - - - - - - - - - - ***Connections to Nature of Science*** **Science is a Human Endeavor** • Advances in technology influence the progress of science and science has influenced advances in technology. (MS-PS4-3)

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts. (MS-PS4-3) **RST.6-8.1** Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-PS4-3) **RST.6-8.2** Compare and contrast the information gained from experiments, simulations, videos, or multimedia sources with that gained from reading	Reason abstractly and quantitatively. (MS-PS4-1) **MP.2** Model with mathematics. (MS-PS4-1) **MP.4** Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-PS4-1) **6.RP.A.1** Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS4-1) **6.RP.A.3**

a text on the same topic. (MS-PS4-3) **RST.6-8.9** Draw evidence from informational texts to support analysis, reflection, and research. (MS-PS4-3) **WHST.6-8.9** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-1),(MS-PS4-2) **SL.8.5**	Recognize and represent proportional relationships between quantities. (MS-PS4-1) **7.RP.A.2** Interpret the equation y = mx + b as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. (MS-PS4-1) **8.F.A.3**

Unit 7: The Electromagnetic Spectrum (20 days)			
This unit is based on:	**SLO**	**Inquiry Menu**	**Quick Links**
MS-PS4-1	Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.	1. Properties of waves: making waves visible. 2. West/Nawaz Inquiry 3. West Web Quest 4. Electromagnetic Math	1. http://betterlesson.com/lesson/633527/the-electromagnetic-spectrum 2. Attachment 3. Attachment 4. http://www.nasa.gov/pdf/574861main_Electromagnetic_Math.pdf
MS-PS4-2	Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.	5. Absorption, Transmission and Reflection: Creating Models 6. Sound Waves vs. Light Waves "Un-notes"	5. http://betterlesson.com/lesson/633209/absorption-transmission-and-reflection-creating-models 6. http://betterlesson.com/lesson/633530/sound-waves-vs-light-waves-un-notes-2-days
MS-PS4-3	Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.	7. Digital vs. Analog Signal Argument from Evidence. 8. Electromagnetic Waves in Communication	7. https://sciencewithmrsbowling.wordpress.com/resources/digital-vs-analog-signal-project/ 8. Attachment.

1. This activity provides demonstrations to make the invisible waves of seismic, radiant and sound energy "visible". There are guided notes provided with inquiry based demonstrations hat the students will complete to understand the difference between key terms (wavelength, medium, amplitude, frequency, crest, trough, transverse, longitudinal, pitch).
2. West/Nawaz Inquiry can go along with both MS-PS4-1 & MS-PS4-2. These inquiry stations involve modeling sound waves, investigating the electromagnetic spectrum, understanding absorption, transmission and reflection through various objects and reflections through concave and convex mirrors.
3. West Web Quest can go along with both MS-PS4-1 & MS-PS4-2. Students explore the different types of waves and their animations, furthermore students will sketch and label the model of each wave. Students will also determine the behavior of waves including reflection, absorption, diffraction, scattering and refraction. Lastly, in a chart students will be able to determine the frequency of each electromagnetic wave along with a description and example.
4. Electromagnetic math provides you with a large manual that allows students to calculate wavelength, frequency and speed of a wave.
5. This lesson provides a formative assessment regarding energy vs. amplitude (MS-PS4-1). The modeling "Mystery Box" Student Activity involves MS-PS4-2 where each group has approximately 6 students – each group is provided with the following terms: "reflection of light, absorption of light, transmission of light, reflection of sound, absorption of sound, transmission of sound". Each group will be given a mystery box that students can utilize to create a model of the term they were assigned. Each student in the group will be modeling one of the terms – along with sharing their model with the group they must describe the evidence they are seeing/hearing.
6. Students are provided with notes that include terms, but questions regarding mini demonstrations that need to be answered. Students will provide evidence that different types of waves interact with matter differently.
7. Students will construct a Venn Diagram to compare and contrast digital signal versus an analog signal. Research the definition for each and place the definition in the appropriate circle for the venn diagram. Use the websites provided to research information and place in each part of the diagram. Watch the videos provided to add more information. When completed, on the back of the Venn Diagram write an argument explaining why digital signals are better than analog signals.
8. This activity contains 7 assignments that will be done in groups of 4. Activities include:
    a. Your first digital message
    b. Digital vs. Analog
    c. Your third message – A Higher Resolution Text
    d. Your second message – a low resolution letter X
    e. Connecting Digital Images to Computer Monitors
    f. Beyond Black and White (Gray and Color)
    g. Sending Digital Movies

Additional resources:
https://sciencewithmrsbowling.wordpress.com/resources/waves-light-and-sound-ms-ps4-1-ms-ps4-2-ms-ps4-3/ - provides several activities that could fit into these three standards.

TOWNSHIP OF UNION PUBLIC SCHOOLS

9th Grade Science

Curriculum Guide

2016

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Academic Area

Science

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Mission Statement

The Township of Union Board of Education believes that every child is entitled to an education designed to meet his or her individual needs in an environment that is conducive to learning. State standards, federal and state mandates, and local goals and objectives, along with community input, must be reviewed and evaluated on a regular basis to ensure that an atmosphere of learning is both encouraged and implemented. Furthermore, any disruption to or interference with a healthy and safe educational environment must be addressed, corrected, or when necessary, removed in order for the district to maintain the appropriate educational setting.

Philosophy Statement

The Township of Union Public School District, as a societal agency, reflects democratic ideals and concepts through its educational practices. It is the belief of the Board of Education that a primary function of the Township of Union Public School System is to formulate a learning climate conducive to the needs of all students in general, providing therein for individual differences. The school operates as a partner with the home and community.

Statement of District Goals

- Develop reading, writing, speaking, listening, and mathematical skills.
- Develop a pride in work and a feeling of self-worth, self-reliance, and self-discipline.
- Acquire and use the skills and habits involved in critical and constructive thinking.
- Develop a code of behavior based on moral and ethical principles.
- Work with others cooperatively.
- Acquire a knowledge and appreciation of the historical record of human achievement and failures and current societal issues.
- Acquire a knowledge and understanding of the physical and biological sciences.
- Participate effectively and efficiently in economic life and the development of skills to enter a specific field of work.
- Appreciate and understand literature, art, music, and other cultural activities.
- Develop an understanding of the historical and cultural heritage.
- Develop a concern for the proper use and/or preservation of natural resources.
- Develop basic skills in sports and other forms of recreation.

Course Description

Ninth Grade Science

The ninth grade Science Curriculum is a continuum of the seventh and eighth grade courses. It elaborates upon and deepens the concepts of environmental and earth science and is designed to immerse students in the physical, biological and earth systems sciences that shape our planet and the environment we live in. Scientific concepts, principals, and modern science practices allow students to analyze the earth and the many processes that shape it as well as exploring beyond earth and the formation of the universe. Environmental issues, both natural and human induced will be studied, and are designed to engage students in evidence-based decision making in real world contexts.

Recommended Textbooks

Environmental Science- Holt McDougal- Heithaus & Arms

Course Proficiencies-Ninth Grade Science

Students will be able to...

1. Understand and follow laboratory and classroom safety rules.
2. Describe the evolution and application of the Theory of Plate Tectonics.
3. Explain the occurrence of volcanism and earthquakes with respect to Plate Tectonics and the Earth's structure.
4. Understand the evolution of life through the study of Geologic Time.
5. Recognize how the dynamic interactions of the Earth, Sun, and Moon influence their lives.
6. Describe the general properties of and relative distances within our solar system.
7. Illustrate or describe the evolution of stars of various mases using the H-R Diagram
8. Investigate and evaluate the various theories pertaining to the formation, evolution, and structure of our Universe, the solar system, and the moon.
9. Appreciate the scope of the relative size differences between the Earth and other members of our solar system, various types of stars, the Milky Way Galaxy, and the Universe.
10. Explain the importance of natural resources and ecosystem services to our lives and the pressures humans put on the global environment.
11. Discuss the effects of population growth and resource consumption and articulate the concepts of sustainability and sustainable development.
12. Explain the fundamentals of matter and chemistry and differentiate among forms of energy, explaining the basics of energy flow and applying them to real-world situations.
13. Compare and contrast the major types of species interactions to characterize feeding relationships and energy flow and using them to construct trophic levels and food webs.
14. Explain biogeochemical cycles and how human impacts can affect them.
15. Define ecosystems and evaluate how living and nonliving entities interact in ecosystem-level ecology.
16. Perceive the scope and assess divergent views on population growth and how human population, affluence, and technology affect the environment.
17. Explain the importance of soils to agriculture and its impacts on soils in the challenge of feeding a growing human population.
18. Describe the main types of pollution (water, air, land) that can affect the health of living things on our planet.
19. Describe Earth's climate system and explain the many factors influencing global climate.
20. Evaluate environmental, political, social, and economic aspects of fossil fuel use and explore the potential for other renewable energy sources.
21. Summarize and compare the types of waste we generate and major approaches to managing it.
22. Managing Waste

Curriculum Units and Pacing Guide

Unit	Instructional Days
Unit 1A: Chemistry of the Universe	25
Unit 1B: Planetary Motion	10
Unit 2: Physics of the Earth System	25
Unit 3: Dynamic Earth Systems	25
Unit 4: Human Activity and the Climate System	25
Unit 5: Human Activity and Sustainability	25
Unit 6: Human Activity and Energy	30

Unit 1A – Chemistry of the Universe

Unit Summary

How can we explain the origin of Earth's chemistry?

In this unit of study, *energy and matter* are studied further by investigating the processes of nuclear fusion and fission that govern the formation, evolution, and workings of the solar system in the universe. Students examine the processes governing the formation, evolution, and workings of the solar system and universe. Some concepts studied are fundamental to science, such as understanding how the matter of our world formed during the Big Bang and within the cores of stars. Others concepts are practical, such as understanding how short-term changes in the behavior of our sun directly affect humans. Engineering and technology play a large role here in *obtaining and analyzing the data* that support the theories of the formation of the solar system and universe. The crosscutting concepts of *patterns; scale, proportion, and quantity; energy and matter; and interdependence of science, engineering, and technology* are called out as organizing concepts for these disciplinary core ideas. Students demonstrate proficiency in *developing and using models; using mathematical and computational thinking, constructing explanations; and obtaining, evaluating, and communicating information;* and to use these practices to demonstrate understanding of the core ideas.

This unit is based on HS-PS1-8, HS-ESS1-3, and HS-ESS1-1. *[Note: The disciplinary core ideas, science and engineering practices, and crosscutting concepts can be taught in either this course or in a high school chemistry course. If this unit is included in the Capstone course, it becomes an Earth and Space science course, rather than an environmental science course.]*

Student Learning Objectives

Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. *[Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]* **(HS-PS1-8)**

Communicate scientific ideas about the way stars, over their life cycle, produce elements. *[Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]* **(HS-ESS1-3)**

Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. *[Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.]* **(HS-ESS1-1)**

Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the

universe. *[Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]* **(HS-ESS1-2)**
Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. *[Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]* **(HS-ESS1-6)**

Part A: *Why is fusion considered the Holy Grail for the production of electricity?*

Why aren't all forms of radiation harmful to living things?

Concepts	Formative Assessment
• Nuclear processes, including fusion, fission, and radioactive decay of unstable nuclei, involve release or absorption of energy. • The total number of neutrons plus protons does not change in any nuclear process. • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.	*Students who understand the concepts are able to:* • Develop models based on evidence to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. • Use simple qualitative models based on evidence to illustrate the scale of energy released in nuclear processes relative to other kinds of transformations. • Develop models based on evidence to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of alpha, beta, and gamma radioactive decays.

Part B: *How do stars produce elements?*

Concepts	Formative Assessment
• The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova	*Students who understand the concepts are able to:* • Communicate scientific ideas in multiple formats (including orally, graphically, textually, and mathematically) about the way stars, over their life cycles, produce elements. • Communicate scientific ideas about the way nucleosynthesis, and therefore

stage and explode. • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.	the different elements it creates, vary as a function of the mass of a star and the stage of its lifetime. • Communicate scientific ideas about how in nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Part C: *Is the life span of a star predictable?*

Concepts	Formative Assessment
• The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. • Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. • The significance of the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth is dependent on the scale, proportion, and quantity at which it occurs.	*Students who understand the concepts are able to:* • Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core in releasing energy that eventually reaches Earth in the form of radiation. • Develop a model based on evidence to illustrate the relationships between nuclear fusion in the sun's core and radiation that reaches Earth.

Part D: *If there was nobody there to Tweet about it, how do we know that there was a Big Bang?*

Concepts	Formative Assessment
• The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. • The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. • Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. • Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.	*Students who understand the concepts are able to:* • Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. • Construct an explanation of the Big Bang theory based on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars). • Construct an explanation based on valid and reliable evidence that energy in the universe cannot be created or destroyed, only moved between one place and another place, between objects and/or fields, or between systems.

• Energy cannot be created or destroyed, only moved between one place and another place, between objects and/or fields, or between systems. • Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. • Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and will continue to do so in the future. • Science assumes the universe is a vast single system in which basic laws are consistent. • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.	

Part E: *How can chemistry help us to figure out ancient events?*

Concepts	Formative Assessment
• Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. • Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. • Much of science deals with constructing explanations of how things change and how they remain stable.	*Students who understand the concepts are able to:* • Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. • Use available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. • Apply scientific reasoning to link evidence from ancient Earth materials, meteorites, and other planetary surfaces to claims about Earth's formation and early history, and assess the extent to which the reasoning and data support the explanation or conclusion. • Use available evidence within the solar system to construct explanations for how Earth has changed and how it remains stable.

What It Looks Like in the Classroom
This unit of study explores the flow of energy and matter but with emphasis on Earth and space science in relation to the history of Earth starting with the Big Bang theory. Students explore the production of elements in stars and radioactive decay. Students develop and use models to illustrate the processes of fission, fusion, and radioactive decay and the scale of energy released in nuclear processes. Models are qualitative, based on evidence, and might include depictions of radioactive decay series such as Uranium-238, chain reactions such as the fission of Uranium-235 in reactors, and fusion within the core of stars. Students also explore the PhET nuclear fission inquiry lab and graphs to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of alpha, beta, and gamma radioactive decays. When modeling nuclear processes, students depict that atoms are not conserved, but the total number of protons plus neutrons is conserved. Models include changes in the composition of the nucleus of atoms and the scale of energy released in nuclear processes. The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. Other than hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. Because atoms of each element emit and absorb characteristic frequencies of light, the presence of an element can be detected in stars and interstellar gases. Students develop an understanding of how analysis of light spectra gives us information about the composition of stars and interstellar gases. Communication of scientific ideas about how stars produce elements is done in multiple formats, including orally, graphically, textually, and mathematically. The conservation of the total number of protons plus neutrons is important in their explanations, and students should cite supporting evidence from text. Students use the sun as a model for the lifecycle of a star. This model should also illustrate the relationship between nuclear fusion in the sun's core and energy that reaches the Earth in the form of radiation. Students construct a mathematical model of nuclear fusion in the sun's core, identifying important quantities and factors that affect the life span of the sun. They use units and consider limitations on measurement when describing energy from nuclear fusion in the sun's core that reaches the Earth. For example, students quantify the amounts of energy in joules when comparing energy sources. In this way, students develop an understanding of how our sun changes and how it will burn out over a lifespan of approximately 10 billion years. This unit continues with a study of how astronomical evidence ("red shift/blue shift," wavelength relationships to energy, and universe expansion) can be used to support the Big Bang theory. Students construct an explanation of the Big Bang theory based on evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. Students explore and cite evidence from text of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of primordial radiation that still fills the universe. The concept of conservation of energy should be evident in student explanations. Students cite specific evidence from text to support their explanations of the life cycle of stars, the role of nuclear fusion in the sun's core, and the Big Bang theory. In their explanations, they discuss the idea that science assumes the universe is a vast single system in which laws are consistent. Students are aware that a scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. Students know that if new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of the new evidence. This unit concludes with the application of scientific reasoning and the use of evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of the Earth's formation and early history. For example, students use examples of spontaneous radioactive decay as a tool to determine the

ages of rocks or other materials (K-39 to Ar-40). Students make claims about Earth's formation and early history supported by data while considering appropriate units, quantities and limitations on measurement. Students construct graphs showing data on the absolute ages and composition of Earth's rocks, lunar rocks, and meteorites. Using available evidence within the solar system, students construct explanations for how the earth has changed and how it has remained stable in its 4.6 billion year history.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Ask and refine questions to support uniform energy distribution among the components in a system when two components of different temperature are combined, using specific textual evidence.
- Conduct short as well as more sustained research projects to determine energy distribution in a system when two components of different temperature are combined.
- Collect relevant data across a broad spectrum of sources about the distribution of energy in a system and assess the strengths and limitations of each source.
- Synthesize findings from experimental data into a coherent understanding of energy distribution in a system.
- Conduct short as well as more sustained research projects to determine how the properties of water affect Earth materials and surface processes.
- Cite specific textual evidence to evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios.
- Evaluate the hypotheses, data, analysis, and conclusions of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios, verifying the data when possible and corroborating or challenging conclusions with other design solutions.
- Integrate and evaluate multiple design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios in order to reveal meaningful patterns and trends.
- Evaluate the hypotheses, data, analysis, and conclusions of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios, verifying the data when possible and corroborating or challenging conclusions with other design solutions.
- Synthesize data from multiple sources of information in order to create data sets that inform design decisions and create a coherent understanding of developing, managing, and utilizing energy and mineral resources.

Mathematics

- Use symbols to represent energy distribution in a system when two components of different temperature are combined, and manipulate the representing symbols. Make sense of quantities and relationships in the energy distribution in a system when two components of different temperature are combined.
- Use a mathematical model to describe energy distribution in a system when two components of different temperature are combined. Identify important quantities in energy distribution in a system when two components of different temperature are combined and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of the properties of water and their effects on Earth materials and surface processes.
- Use symbols to represent an explanation of the best of multiple design solutions for developing, managing, and utilizing energy and mineral resources and manipulate the representing symbols. Make sense of quantities and relationships in cost–benefit ratios for multiple design solutions for developing, managing, and utilizing energy and mineral resources symbolically and manipulate the representing symbols.
- Use a mathematical model to explain the evaluation of multiple design solutions for developing, managing, and utilizing energy and mineral resources. Identify important quantities in cost–benefit ratios for multiple design solutions for developing, managing, and utilizing energy and mineral resources and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Modifications

(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: All Standards, All Students/Case Studies for vignettes and explanations of the modifications.)

- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA).

Research on Student Learning

Students of all ages show a wide range of beliefs about the nature and behavior or particles. They lack an appreciation of the very small size of particles; believe there must be something in the space between particles; have difficulty in appreciating the intrinsic motion of particles in solids, liquids and gases; and have problems in conceptualizing forces between particles (NSDL, 2015).

Prior Learning

Physical science

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Earth and space science

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.
- Earth and its solar system are part of the Milky Way Galaxy, which is one of many galaxies in the universe.
- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

Connections to other Courses
Physical science • Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. • The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places elements with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. • A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. • Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. • Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. • The availability of energy limits what can occur in any system. • Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). • When two objects interacting through a field change relative position, the energy stored in the field is changed. • Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. • Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. • When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. • Photoelectric materials emit electrons when they absorb light of a high-enough frequency. *Earth and space science*

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.
- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.
- Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.
- Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.

Suggested Activities and Samples of Open Education Resources

Solar Fusion: Students develop a model to identify and describe the hydrogen as the Sun's fuel source, helium and energy as the products of nuclear fusion, and the life span of the Sun.

Expansion of the Universe & Four Pillars of Cosmology: Student analyze informational text, animations and videos on the Doppler effect and the observed redshift in the universe. Students apply their learning of the Doppler effect to justify the Big Bang Theory and support their reasoning with evidence from multiple sources.

Extensions:

- Sonic Boom Link: http://www.ck12.org/physics/Doppler-Effect/rwa/Sonic-Boom/
    - Echolocation Link: http://www.ck12.org/physics/Doppler-Effect/rwa/Echolocation/

Universe Evolution & CMB Analyzer: Students analyze several NASA concept animations to develop an explanation for the existence of background radiation and the redshift to defend the argument that the universe is expanding.

Life Cycle of a Star - Students analyze multiple sources of information text and diagrams on the life cycle of a star. Students use the text to determine the relationship between the stars' mass, life cycle and ability to fuse elements and ability to go spread the elements through the universe.

Emission Spectrum of the Sun - Students analyze informational text and a video on how scientists know the composition of the sun. Students use the information to develop a written argument on how scientists can use this method to determine the composition of distant stars.

Interactive HR Diagram - Students manipulate the variables of the HR diagram to determine the relationship between the mass, lifespan, color and size of a star. Students generate conclusion between the mass and the lifespan of the star supported with data from the activity.

Supernova - Students analyze informational text regarding supernova to determine where a supernova takes place, the cause of supernovas and the role of supernovas in the evolution of the universe.

Hubble's Law- Students will analyze electromagnetic spectrums to determine how galaxies are moving in the universe. Students will plot the speed on the "Hubble's

Law" worksheet to create a graph of distance vs velocity. Big Bang Balloon- Students develop authentic models using the materials provided and gather evidence supporting the Big Bang theory. The Universe- Students will watch different episodes displaying computer-generated imagery and computer graphics of astronomical objects in the universe plus interviews with experts who study in the fields of cosmology, astronomy, and astrophysics. Each episode is geared towards a topic of interest.

Appendix A: NGSS and Foundations for the Unit
Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. *[Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]* **(HS-PS1-8)**
Communicate scientific ideas about the way stars, over their life cycle, produce elements. *[Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]* **(HS-ESS1-3)**
Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. *[Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.]* **(HS-ESS1-1)**
Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. *[Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]* **(HS-ESS1-2)**
Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. *[Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]* **(HS-ESS1-6)**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 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. • Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8),(HS-ESS1-1) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS1-2) • Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-ESS1-6) **Obtaining, Evaluating, and Communicating Information** • Communicate scientific ideas (e.g. about phenomena and/or the process of development	**PS1.C: Nuclear Processes** • Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8) **ESS1.A: The Universe and Its Stars** • The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1) • The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2),(HS-ESS1-3) • The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS-ESS1-2) • Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (HS-ESS1-2),(HS-ESS1-3) **ESS1.C: The History of Planet Earth** • Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered	**Energy and Matter** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-ESS1-3), (HS-PS1-8), (HS-ESS1-1) • Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems. (HS-ESS1-2) **Scale, Proportion, and Quantity** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1) • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4) • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8) **Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6) - ***Connections to Engineering, Technology, and Applications of Science*** **Interdependence of Science, Engineering, and Technology** • Science and engineering complement each other in the cycle known as research and development

and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-ESS1-3) • Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. (HS-ESS1-6)	most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. (HS-ESS1-6) **PS3.D: Energy in Chemical Processes and Everyday Life** • Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary) (HS-ESS1-1) **PS4.B: Electromagnetic Radiation** • Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.*(secondary)*HS-ESS1-2)	(R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-2) - ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-ESS1-2) • Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-2) **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-ESS1-2)

English Language Arts/Literacy	Mathematics
Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS1-1) **RST.11-12.1** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ESS1-6) **RST.11-12.8** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-3),(HS-ESS1-2) **WHST.9-12.2** Write arguments focused on *discipline-specific content.* (HS-ESS1-6) **WHST.9-12.1** Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-ESS1-3) **SL.11-12.4**	Reason abstractly and quantitatively. (HS-ESS1-1), (HS-ESS1-2) ,(HS-ESS1-3) , (HS-ESS1-6) **MP.2** Model with mathematics. (HS-ESS1-1), (HS-PS1-8), (HS-ESS1-6) **MP.4** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS1-1),(HS-ESS1-2), (HS-PS1-8), (HS-ESS1-6) **HSN-Q.A.1** Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-1), (HS-ESS1-2), (HS-PS1-8), (HS-ESS1-6) **HSN-Q.A.2** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-1), (HS-ESS1-2), (HS-PS1-8), (HS-ESS1-6) **HSN-Q.A.3** Interpret expressions that represent a quantity in terms of its context. (HS-ESS1-1) **HSA-SSE.A.1** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-ESS1-1), (HS-ESS1-2) **HSA-CED.A.2** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-ESS1-1),(HS-ESS1-2) **HSA-CED.A.4**

Unit 1B – Planetary Motion

Unit Summary

How was it possible for NASA to intentionally fly into Comet Tempel 1?

In this unit of study, students *use mathematical and computational thinking* to examine the processes governing the workings of the solar system and universe. While doing so they *plan and conduct investigations* and *apply scientific ideas* to make sense of Newton's law of gravitation to describe and predict the gravitational forces between objects. The crosscutting concepts of *scale, proportion, and quantity, and patterns* are called out as organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in *using mathematical and computational thinking* and to use this practice to demonstrate understanding of core ideas.

This unit is based on HS-ESS1-4, HS-PS2-4, and HS-PS2-2. *[Note: The disciplinary core ideas, science and engineering practices, and crosscutting concepts can be taught in either this course or in a high school physics course. If this unit is included in the Capstone course, it becomes an Earth and Space science course, rather than an environmental science course.]*

Student Learning Objectives

Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. *[Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]* **(HS-ESS1-4)**

(Secondary to HS-ESS1-4) **Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.** *[Clarification Statement: Coulomb's Law is not addressed in this unit. Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]* **(HS-PS2-4)**

(Secondary to HS-ESS1-4) **Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.** *[Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]* **(HS-PS2-2)**

Part A: *How was it possible for NASA to intentionally fly into Comet Tempel 1?*

Concepts	Formative Assessment
• Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.	*Students who understand the concepts are able to:* • Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. • Use mathematical and computational representations of Newtonian

• Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another. (e.g., linear growth vs. exponential growth).	gravitational laws governing orbital motion that apply to moons and human-made satellites. • Use algebraic thinking to examine scientific data and predict the motion of orbiting objects in the solar system.

What it Looks Like in the Classroom

In this unit of study, students develop an understanding of Kepler's laws, which describe common features of the motions of orbiting objects, including their elliptical paths around the sun. They also learn how orbits may change due to the gravitational effect from, or collisions with, other objects in the solar system. They use algebraic thinking and mathematical and computational representations to examine data and predict the motion of orbiting objects, including moons in our solar system and human-made satellites.

Regarding Kepler's first law, students must have experience in creating scale representations of an ellipse with two foci in order to appreciate that the sun and the center of the solar system's mass are the two foci around which the Earth orbits. Having students actually create ellipses with tacks, cardboard, and string will provide a concrete example of Kepler's first law when calculating the eccentricity of various ellipses ranging in values from 0 to 1. Alternatively, online applets such as the one at Planetary Orbit Simulator may be used to explore the eccentricity of Earth's orbit and those of the other planets in our Solar System. The eccentricity of the Earth's orbit is 0.0167, which is near circular, and even though this value is small it does have implications which are explored within the balance of this unit. Students also use a mathematical model to explain the motion of orbiting objects in the solar system, identifying any important quantities and relationships and using units when appropriate.

Regarding Kepler's second law, students must understand that a line joining a planet and the sun sweeps out equal areas during equal intervals of time. Diagrams could be used to facilitate understanding of this concept. For example, students can use technology such as the Planetary Orbit Simulator to graph an ellipse with an eccentricity of 0.0167. The ellipse can then be divided into equal arc lengths representing time intervals. Next, the area of each wedge can be approximated by finding the area of each approximate triangle. Students should keep accuracy and limitations of measurement in mind while modeling the motion of orbiting objects. Using a pizza that isn't cut symmetrically as an example, ask students where planets are moving fastest and slowest. Ask where areas of greatest centripetal force and acceleration are located.

Students must be able to perform mathematical computations with using Kepler's third law, which states that from the period of a planet's orbit (how long it takes to go around the sun in years), the distance (semi-major axis of the ellipse) of that planet from the sun can be determined.

Kepler's Third Law: $p^2 = a^3$

Kepler observed in the law of harmonies that this ratio is the same for every planet in our solar system. Students should understand the value of one astronomical unit (AU) and the distance from the Earth to the sun (149,597,870.700 kilometers) in order to facilitate calculations for astronomical bodies orbiting our sun. Time can be measured in Earth days or Earth years.

Students must also be able to combine Newton's law of universal gravitation with Kepler's third law to obtain Newton's version of Kepler's third law. This can then be used to describe planetary motion in our solar system with no more than two bodies at a time. Students must be able to predict the motion of human-made satellites as well as planets and moons. Students should be able to describe, for example, why any geosynchronous satellite must always maintain a specific orbit.

Students apply Kepler's and Newton's laws to astronomical data in order to determine the validity of the laws. They might be given astronomical data in the form of numerical tables showing periods and radii. Examples should also include pictorial data of the shapes of orbits of planets in our solar system.

It might be useful to reinforce prior learning of Newton's laws (F=ma, law of inertia) while showing how orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. Students must be able to explain why planetary orbits may change (e.g., the Kessler Effect, perturbations, wobble, etc.).

Students appreciate how astronomers find extrasolar planets, and explain how observations about an orbiting planet can yield information about the mass and location of the star it orbits.

Students analyze data in which variables such as force, mass, period, and radius of orbit are changed in order to visualize the relationships between a central force and an orbiting body within the context of Kepler's laws as well as the law of universal gravitation. For example, lab data or planetary data may be fed into a computer simulation (PhET), and the resulting orbital behavior analyzed for its compliance with Kepler's laws and universal gravitation.

(Refer to NJ High School Physics Model Curriculum Units 1 and 2 for additional classroom integration ideas for the Physics Performance Expectations integrated into this unit.)

Leveraging Mathematics

Mathematics

- Represent the motion of orbiting objects in the solar system symbolically, and manipulate the representing symbols. Make sense of quantities and relationships about the motion of orbiting objects in the solar system symbolically and manipulate the representing symbols.
- Use a mathematical model to explain the motion of orbiting objects in the solar system. Identify important quantities in the motion of orbiting objects in the solar system and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand the motion of orbiting objects in the solar system and to guide the solution of multistep problems; choose and interpret units representing the motion of orbiting objects in the solar system consistently in formulas; chose and interpret the scale and the origin in graphs and data displays representing the motion of orbiting objects in the solar system.
- Define appropriate quantities for the purpose of descriptive modeling of the motion of orbiting objects in the solar system.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing the motion of orbiting objects in the solar system.
- Interpret expressions that represent the motion of orbiting objects in the solar system.
- Create equations in two or more variables to represent relationships between quantities representing the motion of orbiting objects in the solar system; graph equations representing the motion of orbiting objects in the solar system on coordinate axes with labels and scales.
- Rearrange formulas representing the motion of orbiting objects in the solar system to highlight a quantity of interest, using the same reasoning as in solving equations.

Modifications

(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: All Standards, All Students/Case Studies for vignettes and explanations of the modifications.)

- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.

- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA).

Research on Student Learning

Research suggests teaching the concepts of spherical Earth, space, and gravity in close connection to each other. Students typically do not understand gravity as a force and misconceptions about the causes of gravity persist after traditional high-school physics instruction. These misconceptions about the causes of gravity can be overcome by specially designed instruction. Students of all ages may hold misconceptions about the magnitude of the earth's gravitational force. Even after a physics course, many high-school students believe that gravity increases with height above the earth's surface.

High-school students also have difficulty in conceptualizing gravitational forces as interactions between two objects. In particular, they have difficulty in understanding that the magnitudes of the gravitational forces that two objects of different mass exert on each other are equal therefore resulting in a deeper understanding of the relationships between the object as per of measurable phenomenon. The difficulties persist even after specially designed instruction (NSDL, 2015).

Prior Learning

Physical science

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).

Earth and space science

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.
- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

Connections to Other Courses

Physical science

- Newton's second law accurately predicts changes in the motion of macroscopic objects.
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.
- Newton's law of universal gravitation provides the mathematical model to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

Suggested Activities and Samples of Open Education Resources for this Unit *(Refer to NJ High School Physics Model Curriculum Units 1, 2, 6 and 8 for additional open education resources for this unit.)*
Inverse square law for light and Inverse square law - force: Students use the simulators to ask questions and define problems. Students draw conclusions on inverse relationships based on the data from their activity and support their conclusions with evidence from the activity. Orbital Motion Students use the simulation to investigate the nature of an elliptical orbit of a planet or other satellite about the Sun or some central body. Gravity and Orbits: Students analyze the relationship between the Sun, Earth, Moon and space station, including orbits and positions. Students manipulate variables to show how gravity controls the motion of our solar system. Students make predictions how motion would change if gravity was stronger or weaker. Orbital Motion: Students investigate why planets move in ellipses rather than orbits. Kepler's Laws of Planetary Motion: Students use a simulation to launch a spacecraft to Mars applying Kepler's Laws. Students use the simulation to investigate the nature of an elliptical orbit of a planet or other satellite about the Sun or some central body. Orbit of the Space Station Mercury's Deviated Orbit

Appendix A: Foundations for the Unit
Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. *[Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]* **(HS-ESS1-4)**
(Secondary to HS-ESS1-4) **Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.** *[Clarification Statement: Coulomb's Law is not addressed in this unit. Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]* **(HS-PS2-4)**
(Secondary to HS-ESS1-4) **Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.** *[Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]* **(HS-PS2-2)**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking • Use mathematical representations of phenomena to describe explanations. (HS-ESS1-4), (HS-PS2-2; HS-PS2-4) - ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories and laws provide explanations in science. (HS-PS2-4) • Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-4)	**ESS1.B: Earth and the Solar System** • Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4) **PS2.A: Forces and Motion** • Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2) **PS2.B: Types of Interactions** • Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4)	**Scale, Proportion, and Quantity** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4) **Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2) **Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4) ***Connections to Engineering, Technology, and Applications of Science*** **Interdependence of Science, Engineering, and Technology** • Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-4)

Embedded English Language Arts/Literacy	Mathematics
N/A	Reason abstractly and quantitatively. (HS-PS2-2), (HS-PS2-4), (HS-ESS1-4) **MP.2** Model with mathematics. (HS-PS2-2), (HS-PS2-4), (HS-ESS1-4) **MP.4** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-2), (HS-PS2-4), (HS-ESS1-4) **HSN.Q.A.1** Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-2), (HS-PS2-4), (HS-ESS1-4) **HSN.Q.A.2** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-2), (HS-PS2-4), (HS-ESS1-4) **HSN.Q.A.3** Interpret expressions that represent a quantity in terms of its context. (HS-PS2-4), (HS-ESS1-4) **HSA.SSE.A.1** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-4) **HSA.SSE.B.3** Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-2) **HSA.CED.A.1** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-2) **HSA.CED.A.2** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-2) **HSA.CED.A.4**

Unit 2 – Physics of the Earth System

Unit Summary

How much force and energy is needed to move a continent?

Students investigate the energy within the Earth as it drives Earth's surface processes. Students *evaluate evidence* of the past and current movements of continental and oceanic crust for theory of plate tectonics to explain the ages of crustal rocks. Finally, students *develop a model based on evidence* of the Earth's interior to describe the cycle of matter by thermal convection. The crosscutting concepts of *patterns and stability, cause and effect, stability and change, energy and matter,* and *systems and systems models* are called out as organizing concepts for these disciplinary core ideas.

Within this unit, connections to Physical Science Performance Expectations are made. Students *plan and conduct investigations*, and *analyze data and using math to support claims* in order to develop an understanding of ideas related to why some objects keep moving and some objects fall to the ground. Students will also build an understanding of forces and Newton's second law. They will develop an understanding that the total momentum of a system of objects is conserved when there is no net force on the system. Students use mathematical representations to support a claim regarding the relationship among frequency, wavelength, and speed of waves traveling in various media, such as the Earth's layers. Students then apply their understanding of how magnets are created to model the generation of the Earth's magnetic field. The crosscutting concept of *cause and effect* is called out as an organizing theme. Students are expected to demonstrate proficiency *in planning and conducting investigations and developing and using models*. These fundamental physics concepts provide a foundation for understanding the dynamics of Earth motions and processes over deep time.

This unit is based on HS-ESS1-5, HS-ESS2-1, and HS-ESS2-3, *HS-PS2-5* (*secondary to HS-ESS2-3*), and *HS-PS4-1* (*secondary to HS-ESS2-3*). HS-PS2-1 may also be integrated in this unit.

[Note: The disciplinary core ideas, science and engineering practices, and crosscutting concepts can be taught in either this course or in a high school physics course.].

Student Learning Objectives

Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. *[Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).]* **(HS-ESS1-5)**

(Secondary to HS-ESS1-5) **Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.** *[Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]* **(HS-PS2-1)**

Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. *[Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [Assessment Boundary: Assessment does not include memorization of the details of the formation of specific*

geographic features of Earth's surface.] **(HS-ESS2-1)**
Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. *[Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]* **(HS-ESS2-3)**
(Secondary to HS-ESS2-3) **Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.** *[Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.]* **(HS-PS2-5)**
(Secondary to HS-ESS2-3) **Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** *[Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]* **(HS-PS4-1)**

Part A: *How long does it take to make a mountain?*

Concepts	Formative Assessment
• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. • Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. • Change and rates of change can be quantified and modeled over very short or very long periods of time. • Some system changes are irreversible.	*Students who understand the concepts are able to:* • Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. • Develop a model to illustrate how the appearance of land features and sea-floor features are a result of both constructive forces and destructive mechanisms. • Quantify and model rates of change of Earth's internal and surface processes over very short and very long periods of time.

Part B: How much force is needed to move a continent? What can possibly provide the energy for that much force?

Concepts	Formative Assessment
• Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of • Earth with a hot but solid inner core, a liquid outer core, and a solid mantle and crust. • Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. • The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. • Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. • Energy drives the cycling of matter within and between Earth's systems. • Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. • Science knowledge is based on empirical evidence. • Science disciplines share common rules of evidence used to evaluate explanations about natural systems. • Science includes the process of coordinating patterns of evidence with current theory.	*Students who understand the concepts are able to:* • Develop an evidence-based model of Earth's interior to describe the cycling of matter by thermal convection. • Develop a one-dimensional model, based on evidence, of Earth with radial layers determined by density to describe the cycling of matter by thermal convection. • Develop a three-dimensional model of Earth's interior, based on evidence, to show mantle convection and the resulting plate tectonics. • Develop a model of Earth's interior, based on evidence, to show that energy drives the cycling of matter by thermal convection.

Part C: *Are all rocks the same age?*

Concepts	Formative Assessment
• Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million	*Students who understand the concepts are able to:* • Evaluate evidence of the past and current movements of continental and

years old. • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. • Spontaneous radioactive decay follows a characteristic exponential decay law. • Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. • Empirical evidence is needed to identify patterns in crustal rocks.	oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. • Evaluate evidence of plate interactions to explain the ages of crustal rocks.

What it Looks Like in the Classroom

In this unit of study, students apply their knowledge of forces and energy as they examine Earth's dynamic and interacting systems, including the effects of feedback, and develop an understanding of plate tectonics as the unifying theory that explains the past and current movements of the rocks at Earth's surface. Plate tectonics also provides a framework for understanding Earth's geologic history. Students begin by developing models, supported by evidence, to illustrate how the Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean floor features. Students quantify and model long-term and short-term changes in the earth's crust, using examples such as continental drift, mountain building, earthquakes, and volcanic eruptions. Students construct models using drawings, clay, graham crackers, or use mathematical models or video animations to demonstrate an understanding of these concepts. Their models illustrate both constructive (deposition) and destructive (erosion) forces. Students make strategic use of digital media in presentations to enhance understanding of Earth's internal and surface processes and the different spatial and temporal scales at which they operate. Students quantify rates of change of Earth's internal and surface processes over very short and very long periods of time. In any quantitative representations of data, students use units appropriately and consider the accuracy and limitations of any measurements. Students also appreciate that some Earth system changes are irreversible.

Evidence used to create models detail how plate movements are responsible for both continental and ocean floor features and for the distribution of rocks on the Earth's surface. Students examine maps showing the distribution of minerals or fossils to draw inferences regarding how plates have moved over time. Students interpret geological layers to describe the history of Earth events by studying geological maps, core sample data, and fossil records in order to describe and model change and rates of change of Earth events.

Further evidence of plate movement could be determined by mapping earthquakes and volcanoes to show where these types of events are more likely to occur on the Earth's surface. This activity is complemented by referencing catastrophic Earth events that occurred in the last century and throughout the history of the Earth. This shows students how certain systems are predictable over long periods of time. To determine how matter cycles in the Earth's interior, students develop an understanding of how convection cells in the mantle move thermal energy throughout the Earth and how that energy affects superficial movement of the crustal plates. Students perform experiments by creating and observing convection cells. For example, investigations include materials such as a beaker of water containing pepper, raisins, glitter, or rice, placed on a hot plate. Students observe the circular motion of the particles in the water as they move upward in the convection cell over the heat source. They also observe the downward motion of the particles in other areas of the beaker. Connections are made between this type of modeling activity and convection cells in the mantle. Emphasis is placed on the importance of changing temperatures and density in these investigations so students understand the cycling of matter due to the outward flow of energy from Earth's interior and the gravitational movement of denser materials toward the interior. Further discussion of this topic emphasizes how areas of tension over thermal uprisings create divergent boundaries (rifts) and areas of compression over cooling magma create convergent boundaries (subduction zones). Students examine how transform boundaries are created between convection cells flowing in opposite directions. An understanding of the sources of thermal energy within the Earth (radioactive decay, kinetic energy transfer from asteroid collisions, and pressure due to gravity) is also important to understanding convection in the mantle. Students identify important quantities and use appropriate units when describing Earth's interior and the cycling of matter by thermal convection.

In order to develop an understanding of how current representations of the interior of the Earth were developed over time, students research the historical contributions of individuals such as Wegener (continental drift), Vine (bathymetry), and Hess (sonar and bathymetry). Students explain how changes in technology (including mapping of continental shelves, sonar, bathymetry data, high pressure laboratory experiments, and seismic monitoring stations) improved these representations. Students explain the importance of seismic waves (P-waves and S-waves) and shadow zones in understanding the interior of the Earth. Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. Students investigate and research the relative thickness, temperature, and composition of the main layers of the Earth (inner core, outer core, mantle, asthenosphere, lithosphere, and crust) and cite evidence from text to support their findings. Students create models of the interior of the Earth that describe the cycling of matter by thermal convection; these models could include paper and pencil drawings, three-dimensional clay models, or computer animations. Models demonstrate an understanding that Earth has a hot, solid inner core, a liquid outer core, and a solid mantle and crust.

Using knowledge of plate movements, students develop explanations for the ages of crustal rocks. Students begin by identifying major plates and types of boundaries using maps of the Earth's surface showing the location of major plate boundaries, such as the United States Geological Survey (USGS) plate boundary map. Students examine and evaluate evidence illustrating the following:

- Continental crust can be older than 4 billion years as compared to oceanic crust, which is less than 200 million years old, due to the subduction of oceanic crust beneath continental crust.
- The continents do not move over the ocean floor; rather, the entire plate moves over the mantle.
- Radioactive decay follows a characteristic exponential decay law and can be used to determine the ages of rocks and other materials. (Depending on where this course falls in relation to the chemistry course, students may or may not have a quantitative understanding of radioactive decay and half-lives. If this course is sequenced before chemistry, students should use only a qualitative understanding of how nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.)
- Plates moving over hot spots create island chains (e.g., Hawaiian Islands) that can be used to track plate movement.
- Magnetic field lines are formed over time due to geomagnetic reversals. These lines can be used to plot the movement of plates over time. (Data showing how magnetic field lines on the ocean floor change over time will help students appreciate the amount of time and the frequency with which reversals take place.)
- Wilson cycles (taking 500 million years each) show that the continents have separated and come together several times over Earth's history, so that the Earth's surface has reformed about eight times in our 4.5-billion-year history.

Using evidence from their research, students write informative text about the ages of crustal rocks based on past and current movements of continental and oceanic crust. Their explanations include evaluation of hypotheses, data, analysis, and conclusions, and attend to any gaps or inconsistencies. In their accounts, students include narration of historical events and important scientific procedures or experiments.

(Refer to NJ High School Physics Model Curriculum Units 1, 6 and 8 for additional classroom integration ideas for the Physics Performance Expectations integrated into this unit.)

Leveraging English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of Earth's internal and surface processes and the different spatial and temporal scales at which they operate and to add interest.
- Cite specific textual evidence to support analysis of the Earth's interior, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to model the Earth's interior and the cycling of matter by thermal convection to enhance understanding of findings, reasoning, and evidence and to add interest.
- Cite specific textual evidence of past and current movements of continental and oceanic crust to support analysis of the ages of crustal rocks, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Evaluate the hypotheses, data, analysis, and conclusions regarding the ages of crustal rocks based on evidence of past and current movements of continental and oceanic crust, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- Write informative texts about the ages of crustal rocks based on evidence of past and current movements of continental and oceanic crust, including the narration of historical events, scientific procedures/experiments, or technical processes.

Mathematics

- Represent symbolically an explanation for Earth's internal and surface processes and the different spatial and temporal scales at which they operate, and manipulate the representing symbols. Make sense of quantities and relationships about Earth's internal and surface processes and the different spatial and temporal scales at which they operate symbolically, and manipulate the representing symbols.
- Use a mathematical model to explain Earth's internal and surface processes and the different spatial and temporal scales at which they operate. Identify important quantities in Earth's internal and surface processes and the different spatial and temporal scales at which they operate and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand problems and to guide the solution to multistep problems representing Earth's internal and surface processes and the different spatial and temporal scales at which they operate. Choose and interpret units consistently in formulas representing Earth's internal and surface processes and the different spatial and temporal scales at which they operate; choose and interpret the scale and the origin in graphs and data displays representing Earth's internal and surface processes and the different spatial and temporal scales at which they operate.
- Define appropriate quantities for the purpose of descriptive modeling of Earth's internal and surface processes and the different spatial and temporal scales at which they operate.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing Earth's internal and surface processes and the different spatial and temporal scales at which they operate.
- Represent an explanation for the Earth's interior and the cycling of matter by thermal convection symbolically and manipulate the representing symbols. Make sense of quantities and relationships about the Earth's interior and the cycling of matter by thermal convection symbolically and manipulate the representing symbols.

- Use a mathematical model to explain the Earth's interior and the cycling of matter by thermal convection. Identify important quantities in the Earth's interior and the cycling of matter by thermal convection and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand problems and to guide the solution of multistep problems about the Earth's interior and the cycling of matter by thermal convection; choose and interpret units consistently in formulas representing the Earth's interior and the cycling of matter by thermal convection; choose and interpret the scale and the origin in graphs and data displays of the Earth's interior and the cycling of matter by thermal convection.
- Use units as a way to understand problems and to guide the solution of multistep problems about the ages of crustal rocks and past and current movements of continental oceanic crust; choose and interpret units consistently in formulas representing the ages of crustal rocks and past and current movements of continental and oceanic crust; choose and interpret the scale and the origin in graphs and data displays of the ages of crustal rocks and past and current movements of continental and oceanic crust.
- Define appropriate quantities for the purpose of descriptive modeling of the ages of crustal rocks based on evidence of past and current movements of continental and oceanic crust.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities related to the ages of crustal rocks based on evidence of past and current movements of continental and oceanic crust.
- Represent symbolically an explanation for the ages of crustal rocks based on evidence of past and current movements of continental and oceanic crust, and manipulate the representing symbols. Make sense of quantities and relationships about the ages of crustal rocks based on evidence of past and current movements of continental and oceanic crust symbolically and manipulate the representing symbols.

Modifications

(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: All Standards, All Students/Case Studies for vignettes and explanations of the modifications.)

- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.

- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA).

Research on Student Learning

Students of all ages may hold the view that the world was always as it is now, or that any changes that have occurred must have been sudden and comprehensive. The students in these studies did not, however, have any formal instruction on the topics investigated. Moreover, middle-school students taught by traditional means are not able to construct coherent explanations about the causes of volcanoes and earthquakes.

High-school students also have difficulty in conceptualizing gravitational forces as interactions between two objects. In particular, they have difficulty in understanding that the magnitudes of the gravitational forces that two objects of different mass exert on each other are equal therefore resulting in a deeper understanding of the relationships between the object as per of measurable phenomenon. The difficulties persist even after specially designed instruction (NSDL, 2015).

Prior Learning

Physical science

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.
- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.

- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).
- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- A system of objects may also contain stored (potential) energy, depending on their relative positions.
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.
- A sound wave needs a medium through which it is transmitted.
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Life science

- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

Earth and space science

- The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.
- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.
- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and

spread apart.

- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
- Global movements of water and its changes in form are propelled by sunlight and gravity.
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.
- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

Connections to Other Courses

Physical science

- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).
- When two objects interacting through a field change relative position, the energy stored in the field is changed.
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.
- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.

- Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.

Earth and space science

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust.
- Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.
- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.
- The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection.
- Plate tectonics can be viewed as the surface expression of mantle convection.
- Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.

Suggested Activities and Samples of Open Education Resources for this Unit

(Refer to NJ High School Physics Model Curriculum Units 1, 2, 6 and 8 for additional open education resources for this unit.)

EarthViewer (IPad or Android) or for Chrome browsers: Students explore the co-evolution of the geology and biology found on Earth to develop arguments from evidence for the co-evolution of geology and biology found on Earth. If IPads, Androids or Chrome browsers are not available, similar interactives may be found at this link, and this link.

Le Pichon's 1968 seafloor age data: Students map and analyze LePichon's field data to identify patterns in the ages of the ocean floor.

Extensions: Additional maps and data may be found at NOAA Marine Geology and Geophysics and from their image site. An associated research paper may be found here.

Citation for research paper: Muller, R. D., M. Sdrolias, C. Gaina, and W. R. Roest (2008), Age, spreading rates, and spreading asymmetry of the world's ocean crust, Geochem. Geophys. Geosyst., 9, Q04006, doi:10.1029/2007GC001743.

IRIS - Measuring the Rate of Plate Motion: Students compare GPS data of plate motion to determine the rate at which tectonic plates move. Alternatively, students use real-time plate motion data from UNAVCO to determine the rate at which plates move.

IODP: Deep Earth Academy Core Data investigations: Students investigate seafloor core data to evaluate multiple lines of evidence to support the dynamic plate theory.

GeoMapApp and GeoMapApp educational activities: Students visualize and explore various lines of evidence for plate dynamics and evaluate the strengths of each line of evidence in supporting the dynamic plate theory.

Lithosphere age research paper: Students read this article which describes how seismic data is used to determine the age of the crust, and the inherent issues associated with the procedure. They use this information in their analysis, evaluation, and synthesis of evidence for the dynamic plate theory.

Citation for research paper: Poupinet, G., Shapiro, N.M., Worldwide distribution of ages of the continental lithosphere derived from a global seismic tomographic model, Lithos (2008), doi:10.1016/j.lithos.2008.10.023.

Google Earth Age of the Lithosphere: Students compare the age of the seafloor and continental crust using the data at this site, or USGS data found here or found here.

Geologic time and rates of landscape evolution: Students model rates of landscape evolution to gain an understanding of change over deep, historical, and recent time. Alternatively, students compare rates of erosion of a mountain landscape to agricultural lands by completing this activity.

Hotspot Lesson: Students analyze the rate of movement of the Hawaiian Island chain to further understand rates of change in geologic processes.

How Erosion Builds Mountains: by Mark Brandon and Nicholas Pinter, from Scientific American. Students read this article and identify feedbacks in the mountain building process. To support their model, they gather supporting evidence using this Isostasy model.

Comparing models of the Earth's interior from data: Students compare two models of the Earth's interior and argue from evidence which model more strongly supports the evidence. Seismic Wave: Students receive additional practice in the interpretation of seismic data to model the interior of the Earth.

How the Earth was Made: Watch a documentary explaining the geological and biological history of Earth, from its formation 4.5 billion years ago to the present day.

Student Learning Objectives
Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. *[Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).]* **(HS-ESS1-5)**
(Secondary to HS-ESS1-5) **Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.** *[Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]* **(HS-PS2-1)**
Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. *[Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.]* **(HS-ESS2-1)**
Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. *[Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]* **(HS-ESS2-3)**
(Secondary to HS-ESS2-3) **Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.** *[Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.]* **(HS-PS2-5)**
(Secondary to HS-ESS2-3) **Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** *[Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]* **(HS-PS4-1)**

<table>
<tr><td colspan="3">The Student Learning Objectives above were developed using the following elements from the NRC document A Framework for K-12 Science Education:</td></tr>
<tr><th>Science and Engineering Practices</th><th>Disciplinary Core Ideas</th><th>Crosscutting Concepts</th></tr>
<tr>
<td>Analyzing and Interpreting Data
• Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1)
Using Mathematics and Computational Thinking
• Use mathematical representations of phenomena to describe explanations. (HS-PS4-1)
Planning and Carrying Out Investigations
• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-5)
Developing and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-1; HS-ESS2-3)
Engaging in Argument from Evidence
• Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-ESS1-5)</td>
<td>ESS1.C: The History of Planet Earth
• Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. (HS-ESS1-5)
ESS2.A: Earth Materials and Systems
• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. A deep knowledge of how feedbacks work within and among Earth's systems is still lacking, thus limiting scientists' ability to predict some changes and their impacts. (HS-ESS2-1)
• Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. (HS-ESS2-3)
ESS2.B: Plate Tectonics and Large-Scale System Interactions
• Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) (secondary to HS-ESS1-5),(HS-ESS2-1)</td>
<td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1; HS-PS2-5; HS-PS4-1)
Energy and Matter
• Energy drives the cycling of matter within and between systems. (HS-ESS2-3)
Stability and Change
• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS2-1)
Patterns
• Empirical evidence is needed to identify patterns. (HS-ESS1-5)
- - - - - - - - - - - - - - - - - - - -
Connections to Engineering, Technology, and Applications of Science
Interdependence of Science, Engineering, and Technology
• Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS2-3)</td>
</tr>
</table>

------------------------------- ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories and laws provide explanations in science. (HS-PS2-1) • Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1) **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based on empirical evidence. (HS-ESS2-3) • Science disciplines share common rules of evidence used to evaluate explanations about natural systems. (HS-ESS2-3) • Science includes the process of coordinating patterns of evidence with current theory. (HS-ESS2-3)	• Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (ESS2.B Grade 8 GBE) (HS-ESS2-1) • The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. (HS-ESS2-3) **PS1.C: Nuclear Processes** • Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (secondary to HS-ESS1-5) **PS2.A: Forces and Motion** • Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) **PS2.B: Types of Interactions** • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-5) **PS4.A: Wave Properties** • The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1)	

Embedded English Language Arts/Literacy	Mathematics
Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS2-1), (HS-ESS1-5), (HS-ESS2-3) **RST.11-12.1** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ESS1-5) **RST.11-12.8** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-5) **WHST.9-12.7** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5) **WHST.11-12.8** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1), (HS-PS4-1) **RST.11-12.7** Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1), (HS-PS2-5), **WHST.11-12.9** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-5) **WHST.9-12.2** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-ESS2-1), (HS-ESS2-3) **SL.11-12.5**	Reason abstractly and quantitatively. (HS-PS2-1), (HS-PS4-1), (HS-ESS1-5), (HS-ESS2-1), (HS-ESS2-3) **MP.2** Model with mathematics. (HS-PS2-1), (HS-PS4-1), (HS-ESS2-1), (HS-ESS2-3) **MP.4** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1), (HS-PS2-5), (HS-ESS1-5), (HS-ESS2-1), (HS-ESS2-3) **HSN.Q.A.1** Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1), (HS-PS2-5), (HS-ESS1-5), (HS-ESS2-1), (HS-ESS2-3) **HSN.Q.A.2** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1), (HS-PS2-5), (HS-ESS1-5), (HS-ESS2-1), (HS-ESS2-3) **HSN.Q.A.3** Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1), (HS-PS2-4), (HS-PS4-1) **HSA.SSE.A.1** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1), (HS-PS4-1) **HSA.SSE.B.3** Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1) **HSA.CED.A.1** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-1) **HSA.CED.A.2** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1) (HS-PS4-1) **HSA.CED.A.4** Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. (HS-PS2-1) **HSF-IF.C.7** Represent data with plots on the real number line (dot plots, histograms, and box plots). (HS-PS2-1) **HSS-IS.A.1**

Unit 3 – Dynamic Earth Systems

Unit Summary

How can one explain and predict interactions between Earth materials and within Earth systems?

In this unit of study, *planning and carrying out investigations, analyzing and interpreting data, developing and using models,* and *engaging in arguments from evidence* are key practices to explore the dynamic nature of Earth systems. Students apply these practices to illustrate how Earth's interacting systems cause feedback effects on other Earth systems, to investigate the properties of water and its effects on Earth materials and surface processes, and to model the cycling of carbon through all of the Earth's spheres. Students seek evidence to construct arguments about the simultaneous co-evolution of the Earth's systems and life on Earth. The crosscutting concepts of *energy and matter, structure and function,* and *stability and change* are called out as organizing concepts for these disciplinary core ideas.

This unit is based on HS-ESS2-7. *[Note: The disciplinary core ideas, science and engineering practices, and crosscutting concepts can be taught in either this course or in a high school chemistry course.]*

Student Learning Objectives

Construct an argument based on evidence about the simultaneous co-evolution of Earth's systems and life on Earth. *[Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.]* [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.] (HS-ESS2-7)

Part A: *How do living organisms alter Earth's processes and structures?*

Concepts	Formative Assessment
• The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.	*Students who understand the concepts are able to:* • Construct an argument based on evidence about the simultaneous co-evolution of Earth's systems and life on Earth.

What It Looks Like in the Classroom
Since the Earth formed there has been a co-evolution of Earth's systems and life on Earth. Students explore multiple lines of evidence found in scientific research papers that support this claim, such as the scientific explanations about the composition of the Earth's atmosphere shortly after its formation; current atmospheric composition; evidence for the emergence of photosynthetic organisms; evidence of the effect of the presence of free oxygen on evolution and processes in the other Earth systems; and other evidence that changes in the biosphere affect Earth systems. Students might use a jigsaw activity to explore selected research papers. While reading these papers students identify the methods employed by the scientists, and interpret the data and data visualizations provided in the papers. From this, they evaluate and critique the claims by the scientists. After investigating a variety of research papers, students select at least two examples to construct oral and written logical arguments about the evolution of photosynthetic organisms led to drastic changes in Earth's atmosphere and oceans in which the free oxygen produced caused worldwide deposition of iron oxide formations, increased weathering due to an oxidizing atmosphere and the evolution of animal life that depends on oxygen for respiration; or identify causal links and feedback mechanisms between changes in the biosphere and changes in Earth's other systems.

Connecting with English Language Arts/Literacy
English Language Arts/Literacy • Write arguments focused on discipline-specific content related to the simultaneous co-evolution of Earth's systems and life on Earth.

Modifications
(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: All Standards, All Students/Case Studies for vignettes and explanations of the modifications.) • Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community. • Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling). • Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies). • Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences). • Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings. • Use project-based science learning to connect science with observable phenomena.

- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA).

Research on Student Learning

Students of all ages may hold the view that the world was always as it is now, or that any changes that have occurred must have been sudden and comprehensive. The students in these studies did not, however, have any formal instruction on the topics investigated. Moreover, middle-school students taught by traditional means are not able to construct coherent explanations about the causes of volcanoes and earthquakes. (NSDL, 2015).

Prior Learning

Life science

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Growth of organisms and population increases are limited by access to resources.
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.
- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.
- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.
- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.
- The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.
- Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.
- Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy.
- Natural selection leads to the predominance of certain traits in a population, and the suppression of others.
- In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.
- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

Connections to Other Courses

Life science

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.
- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
- Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.
- Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.
- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.
- Natural selection leads to adaptation that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
- Adaptation also means that the distribution of traits in a population can change when conditions change.
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species.
- Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.

Suggested Activities and Samples of Open Education Resources

MY NASA DATA: Students select satellite datasets to answer questions related to system interactions and feedbacks.

Finding the Crater: Students "visit" different K-T boundary sites, evaluate the evidence found in the cores at each site, find these sites on a map, and predict where the impact crater is located.

Images of Change: Students explore these images of the impacts of climate change over time to develop explanations from evidence of how an impact in one component of the Earth system has effects in other components of the Earth system.

Climate Reanalyzer: Students use the Environmental Change Model of the Climate Reanlyzer to study the feedbacks in the climate system.

USGS Realtime Water data and Climate data: Students create and run an investigation to determine the relationship between streamflow and precipitation data, or another parameter.

Greenhouse Effect: Students explore the atmosphere during the ice age and today. What happens when you add clouds? Change the greenhouse gas concentration and see how the temperature changes. Then compare to the effect of glass panes. Zoom in and see how light interacts with molecules. Do all atmospheric gases contribute to the greenhouse effect?

Earth Systems Activity: Students model the carbon cycle and it's connection with Earth's climate.

Carbon and Climate: Students run a model of carbon sources and sinks and interpret results to develop their own model of the relationship of the carbon cycle to the Earth's climate. Students can also work through the content of the entire module called Carbon Connections which includes numerous models and interactives to gain a deeper understanding of the role of carbon in the climate system.

EarthViewer (IPAd or Android) or for Chrome browsers: Students explore the co-evolution of the geology and biology found on Earth to develop arguments from evidence for the co-evolution of geology and biology found on Earth. If IPads, Androids or Chrome browsers are not available, similar interactives may be found at this link, and this link.

Appendix A: NGSS and Foundations for the Unit

Construct an argument based on evidence about the simultaneous co-evolution of Earth's systems and life on Earth. *[Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.]* [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.] (**HS-ESS2-7**)

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-ESS2-2) **Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-ESS2-5) **Developing and Using Models** • Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-6) **Engaging in Argument from Evidence** • Construct an oral and written argument or counter-arguments based on data and evidence. (HS-ESS2-7)	**ESS2.E Biogeology** • The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS2-7)	**Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS2-2) • Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS2-7) **Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-ESS2-5) **Energy and Matter** • The total amount of energy and matter in closed systems is conserved. (HS-ESS2-6) - - - - - - - - - - **Influence of Engineering, Technology, and Science on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS2-2)

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-ESS2-2)* **RST.11-12.1** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. *(HS-ESS2-2)* **RST.11-12.2** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-ESS2-5) **WHST.11-12.7** Write arguments focused on *discipline-specific content.* (HS-ESS2-7) **WHST.9-12.1**	Reason abstractly and quantitatively. (HS-ESS2-2), (HS-ESS2-6) **MP.2** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS2-2), (HS-ESS2-6) **HSN.Q.A.1** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-2), (HS-ESS2-5), (HS-ESS2-6) **HSN.Q.A.3** Model with mathematics. (HS-ESS2-6) **MP.4** Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS2-6) **HSN.Q.A.2**

Unit 4 – Human Activity & Climate System

Unit Summary

What controls climate?

In this unit of study, students *evaluate claims, analyze and interpret data*, and *develop and use models* to explore the core ideas centered on the Earth's climate system. Students evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by the atmosphere and Earth's various surfaces. They apply these core ideas when they use a quantitative model to describe how variations in the flow of energy into an out of the Earth's systems result in changes in climate, and how carbon is cycle through all of the Earth's spheres. They analyze geoscience data to make the claim that one change to Earth's surface can cause changes to other Earth systems, such as the climate system. Finally, students analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. The crosscutting concepts of *cause and effect, stability and change, energy and matter, and structure and function* are called out as an organizing concept for these disciplinary core ideas.

This unit is based on HS-ESS2-4, HS-PS4-4, HS-ESS2-2, and HS-ESS1-4.

Student Learning Objectives

Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. *[Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]* **HS-ESS2-4**

(secondary to HS-ESS2-4) **Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.** *[Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.]* **HS-PS4-4**

Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. *[Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]* **HS-ESS2-2** (This SLO is repeated here and can also be found in Capstone Science Unit 3)

(Secondary to HS-ESS2-4) **Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.** *[Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.]* [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.] **HS-ESS1-4** (Optional SLO to include when engaging students in the Milankovich cycles.)

Part A: *What happens if we change the chemical composition of our atmosphere?*

Concepts	Formative Assessment
• The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. • Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. • The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. • Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. • Science arguments are strengthened by multiple lines of evidence supporting a single explanation.	*Students who understand the concepts are able to:* • Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. • Use empirical evidence to differentiate between how variations in the flow of energy into and out of Earth's systems result in climate changes. • Use multiple lines of evidence to support how variations in the flow of energy into and out of Earth's systems result in climate changes.

Part B: *How does carbon cycle among the hydrosphere, atmosphere, geosphere, and biosphere? (repeated from Capstone ESS Unit 3)*

Concepts	Formative Assessment
• Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. • Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.	*Students who understand the concepts are able to:* • Develop a model based on evidence to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. • Develop a model based on evidence to illustrate the biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and

• The total amount of energy and matter in closed systems is conserved. • The total amount of carbon cycling among and between the hydrosphere, atmosphere, geosphere, and biosphere is conserved.	biosphere, providing the foundation for living organisms.

Part C: *How do changes in the geosphere effect the atmosphere? (repeated from Capstone Science Unit 3)*

Concepts	Formative Assessment
• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. • The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. • Feedback (negative or positive) can stabilize or destabilize a system. • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.	*Students who understand the concepts are able to:* • Analyze geoscience data using tools, technologies, and/or models (e.g., computational, mathematical) to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

Part D: *What happens to solar energy as it moves through the atmosphere and strikes a surface?*

Concepts	Formative Assessment
• When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X- rays, gamma rays) can ionize atoms and cause damage to living cells. • Cause-and-effect relationships can be suggested and predicted for electromagnetic radiation systems when matter absorbs different frequencies of light by examining what is known about smaller scale mechanisms within the system.	*Students who understand the concepts are able to:* • Evaluate the validity and reliability of multiple claims in published materials about the effects that different frequencies of electromagnetic radiation have when absorbed by matter. • Evaluate the validity and reliability of claims that photons associated with different frequencies of light have different energies and that the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. • Give qualitative descriptions of how photons associated with different frequencies of light have different energies and how the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. • Suggest and predict cause-and-effect relationships for electromagnetic

	radiation systems when matter absorbs different frequencies of light by examining what is known about smaller scale mechanisms within the system.

What It Looks Like in the Classroom
This unit of study focuses on weather and climate and the cause-and-effect relationships between human activity and the climate system. Students develop an understanding of how the foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. They also examine how cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the Earth. These phenomena cause a cycle of ice ages and other gradual climate changes. Students conduct research to locate and analyze data sets showing these phenomena. In order to determine how changes in the atmosphere due to human activity have increased the carbon dioxide concentrations and affected climate, students should look at cycles of differing timescales and their effects on climate. Geoscience data is used to explain climate change over a wide-range of timescales, including one to ten years: large volcanic eruptions, ocean circulation; ten to hundreds of years: changes in human activity, ocean circulation, solar output; tens of thousands to hundreds of thousands of years: changes to Earth's orbit and the orientation of its axis; and tens of millions to hundreds of millions of years: long-term changes in atmospheric composition. Students might also explore Earth's climate history through an analysis of datasets such as the Keeling Curve or Vostok ice core data. Students use a jigsaw activity to examine data for an assigned timescale and event to show cause-and-effect relationships among energy flow into and out of Earth's systems and the resulting in changes in climate. Students use models to describe how variations in the composition of the atmosphere and Earth's surface coupled with variations in the flow of energy into and out of Earth's systems result in changes in climate. Models should be supported by multiple lines of evidence, and students should use digital media in presentations to enhance understanding. Students might use mathematical models, and they should identify important quantities and map relationships using charts and graphs. Mathematical models include appropriate units and limitations on measurement are considered. Students review their study of Unit 3 – Dynamic Earth Systems by examining the history of the atmosphere. Students research the early atmospheric components and the changes that occurred due to plants and other organisms removing carbon dioxide and releasing oxygen. By studying the carbon cycle, students revisit the idea that matter and energy within a closed system are conserved among the hydrosphere, atmosphere, geosphere, and biosphere. Students extend their understanding of how human activity affects the concentration of carbon dioxide in the environment and therefore climate. Students' experiences include synthesizing information from multiple sources and developing quantitative models based on evidence to describe the cycling of carbon among the ocean, atmosphere, soil, and biosphere. Through computer simulations and other studies, important discoveries are still being made about how the ocean, atmosphere, and biosphere interact and are modified in response to human activities. Students describe the boundaries of Earth's systems by looking at models, data sets, or graphics showing temperatures and currents of the ocean and atmosphere. They should identify evidence to support the claim that human activity can modify Earth's systems, especially the climate system. When students are investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Students analyze and describe the inputs and outputs of Earth's systems by researching and investigating the amount of carbon dioxide produced by human activities. In their research, students integrate and evaluate multiple sources of information and verify data when possible. Students then design a solution to decrease the amount of carbon dioxide added by human activity. The design process may need to be broken down into logical steps that can be approached systematically, and decisions about the priority of certain criteria over others should be considered throughout the process.

Current global models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models depend on the amount of human-generated greenhouse gases added to the atmosphere each year and on the ways in which these gases are absorbed by the ocean and biosphere. Students use computational representations of geoscience data to illustrate these relationships and make forecasts about Earth's systems. Students illustrate how relationships are being modified due to human activity by graphing temperature changes over a period of time. Rates of change should be quantified and modeled at different time scales. In symbolic representations of relationships between Earth's systems and human activity, students consider appropriate quantities and limitations on measurement when reporting data.

(Refer to Physical Science Model Curriculum Unit 7 for additional teaching resources for HS-PS4-4)

(Refer to Capstone Science Model Curriculum Unit 1B for additional teaching resources related to HS-ESS1-4)

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence related to our knowledge of feedbacks in the Earth system, attending to the research methodologies the author employed to generate the evidence.
- Cite specific textual evidence describing how different climate models were created while attending to the specific data including in the model and the resolution of the models.
- Refer to journal articles related to a component of the climate system, synthesize the information and tie it back to the research back to the functioning of the entire climate system.
- Refer to journal articles written by scientists describing the research included in the creation of climate models. Synthesize the information and share it with your classmates.
- Select a digital media to display the solution to a climate change issue.
- Focusing on an aspect of the climate system, select a digital media format, and create a presentation that accurately explains the functioning of that particular aspect of the climate system.

Mathematics

- Represent symbolically an explanation for how variations in the flow of energy into and out of Earth's systems result in changes in climate, and manipulate the representing symbols. Use symbols to make sense of quantities and relationships about how variations in the flow of energy into and out of Earth's systems result in changes in climate, symbolically and manipulate the representing symbols.
- Use a mathematical model to explain how variations in the flow of energy into and out of Earth's systems result in changes in climate. Identify important quantities in variations in the flow of energy into and out of Earth's systems result in changes in climate and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand problems and to guide the solution of multistep problems about how variations in the flow of energy into and out of Earth's systems result in changes in climate; choose and interpret units consistently in formulas representing how variations in the flow of energy into and out of Earth's systems result in changes in climate; choose and interpret the scale and the origin in graphs and data displays representing how variations in the flow of energy into and out of Earth's systems result in changes in climate.

- Define appropriate quantities for the purpose of descriptive modeling of how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- Represent symbolically the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere, and manipulate the representing symbols. Make sense of quantities and relationships in the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- Use a mathematical model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. Identify important quantities in the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere; choose and interpret units consistently in formulas representing the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere; choose and interpret the scale and the origin in graphs and data displays representing the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- Define appropriate quantities for the purpose of descriptive modeling of the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- XDefine appropriate quantities for the purpose of descriptive modeling of relationships among changes in climate and its influence on human activity.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities showing relationships among changes in climate and its influence on human activity.

Modifications

(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: All Standards, All Students/Case Studies *for vignettes and explanations of the modifications.)*

- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.

- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA).

Research on Student Learning

Students of all ages (including college students and adults) have difficulty understanding what causes the seasons. Students may not be able to understand explanations of the seasons before they reasonably understand the relative size, motion, and distance of the sun and the earth. Many students before and after instruction in earth science think that winter is colder than summer because the earth is further from the sun in winter. This idea is often related to the belief that the earth orbits the sun in an elongated elliptical path. [3] Other students, especially after instruction, think that the distance between the northern hemisphere and the sun changes because the earth leans toward the sun in the summer and away from the sun in winter. Students' ideas about how light travels and about the earth-sun relationship, including the shape of the earth's orbit, the period of the earth's revolution around the sun, and the period of the earth's rotation around its axis, may interfere with students' understanding of the seasons. [5] For example, some students believe that the side of the sun not facing the earth experiences winter, indicating confusion between the daily rotation of the earth and its yearly revolution around the sun.

Students of all ages (including college students) may believe that air exerts force or pressure only when it is moving and only downwards. Only a few middle-school students use the idea of pressure differences between regions of the atmosphere to account for wind; instead they may account for winds in terms of visible moving objects or the movement of the earth.

Before students understand that water is converted to an invisible form, they may initially believe that when water evaporates it ceases to exist, or that it changes location but remains a liquid, or that it is transformed into some other perceptible form (fog, steam, droplets, etc.). With special instruction, some students in 5th grade may be able to identify the air as the final location of evaporating water. Students must accept air as a permanent substance before they can identify the air as the final location of evaporating water. [12] For many students, difficulty understanding the existence of water vapor in the atmosphere persists in middle school years. Students can understand rainfall in terms of gravity once they attribute weight to little drops of water (typically in upper elementary grades), but the mechanism through which condensation occurs may not be understood until high school.

Students of all ages may confuse the ozone layer with the greenhouse effect, and may have a tendency to imagine that all environmentally friendly actions help to solve all environmental problems (for example, that the use of unleaded petrol reduces the risk of global warming). Students have difficulty linking relevant elements of knowledge when explaining the greenhouse effect and may confuse the natural greenhouse effect with the enhancement of that effect (NSDL, 2015).

Prior Learning

Physical science

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.

- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- A system of objects may also contain stored (potential) energy, depending on their relative positions.
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.
- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.
- Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Life science

- Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.
- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.
- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.
- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

Earth and space science

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.
- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.
- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
- Global movements of water and its changes in form are propelled by sunlight and gravity.
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.
- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- Because these patterns are so complex, weather can only be predicted probabilistically.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.
- Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.
- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.
- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.
- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of

climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Connections to Other Courses

Physical science

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.
- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.
- Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter

than their surrounding environment cool down).

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.
- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

Life science

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
- Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.
- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning

and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

Earth and space sciences

- Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.
- Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.
- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.
- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.
- Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

Suggested Activities and Samples of Open Education Resources

Glaciers: Students will explain how environmental conditions (temperature and precipitation) impact glacial mass budget; identify where snow accumulates in a glacier and justify why.

MY NASA DATA: Students gather, display, and interpret incoming and outgoing solar radiation data to develop a model of the interactions of Earth's various surface types and incoming solar radiation.

Solar Variability & Orbital Cycles: Students select scientific readings and datasets and identify relationships among solar variability, orbital cycles, and Earth's climate over various time scales. Modification of OER: Ice Cores and Orbital variations: Students apply the output of this visualization to develop a model of orbital changes as related to Earth's temperature over deep time.

Climate Reanalyzer: Students use the data on this website to assess diurnal, monthly, seasonal, and annual changes in the weather and climate parameters. Alternatively, data may be acquired from NASA NEO or NASA Giovanni.

Climate Reanalyzer: Students use the Environmental Change Model of the Climate Reanlyzer to study the feedbacks in the climate system.

Climate Modeling 101: Students use the information in this tutorial to understand how climate models are created and interpreted. They apply what they learn to the climate model outputs they interpret.

Carbon Cycle Lesson Plan: Students develop and apply basic and/or advanced mathematical modeling skills to climate modeling.

Paleoclimate Data Access: Students select from various paleoclimate datasets. After they understand how the data was collected and how it is interpreted, they display and analyze the data. They interpret the data and seek relationships among the datasets in order to understand changes in the Earth's climate over time.

Carbon Connections Climate Model: Students control the inputs of various climate forcings to observe the outputs on the climate system. Students can also work through the content of the entire module called Carbon Connections which includes numerous models and interactives to gain a deeper understanding of the role of carbon in the climate system.

NASA - Climate Change Impacts and EPA - Climate Change Impacts: Students construct an explanation and cite evidence for how changes in climate have influenced human activity.

Images of Change: Students explore these images of the impacts of climate change over time to develop explanations from evidence of how an impact in one component of the Earth system has effects in other components of the Earth system.

The Day After Tomorrow- Student's will be able to gain a better understanding for climate change through visual representation of climate effects.

Appendix A: NGSS and Foundations for the Unit
Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. *[Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]* **(HS-ESS2-4)**
(secondary to HS-ESS2-4) **Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.** *[Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.]* **(HS-PS4-4)**
Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. *[Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]* **(HS-ESS2-2)** (This SLO is repeated here and can also be found in Capstone ESS Unit 3)
(Secondary to HS-ESS2-4) **Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.** [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] *[Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]* **(HS-ESS1-4)** (Optional SLO to include when engaging students in the Milankovich cycles.)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information • Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-PS4-4) **Developing and Using Models** • Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4), (HS-ESS2-6) **Analyzing and Interpreting Data** • Analyze data using computational models in order to make valid and reliable scientific claims. (HS-ESS2-1), (HS-ESS3-5) **Using Mathematical and Computational Thinking** • Use mathematical or computational representations of phenomena to describe explanations. (HS-ESS1-4) - ***Connections to Nature of Science*** **Scientific Investigations Use a Variety of Methods** • Science investigations use diverse methods and do not always use the same set of procedures to obtain data. (HS-ESS3-5) • New technologies advance scientific knowledge. (HS-ESS3-5) **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based on empirical evidence. (HS-ESS3-5) Science arguments are strengthened by multiple	**PS4.B: Electromagnetic Radiation** • When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4) **ESS1.B: Earth and the Solar System** • Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. *(secondary to HS-ESS2-4)* **ESS2.A: Earth Materials and Systems** • The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4) • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-2) **ESS2.D: Weather and Climate**	**Cause and Effect** • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS4-4), (HS-ESS2-4) **Scale, Proportion, and Quantity** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4) **Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS2-2), (HS-ESS3-5) **Energy and Matter** • The total amount of energy and matter in closed systems is conserved. (HS-ESS2-6) - ***Connections to Engineering, Technology. and Applications of Science*** **Influence of Engineering, Technology, and Science on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS2-2) • Science and engineering complement each other in the cycle known as research and development

lines of evidence supporting a single explanation. (HS-ESS2-4),(HS-ESS3-5)	• The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-2), (HS-ESS2-4) • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6) • Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6),(HS-ESS2-4) **ESS3.D: Global Climate Change** • Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5) **ESS1.B: Earth and the Solar System** • Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4)	(R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-4)

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS2-2), (HS-ESS3-5) **RST.11-12.1** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (HS-ESS2-2), (HS-ESS3-5) **RST.11-12.2** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to	Reason abstractly and quantitatively. (HS-ESS2-2), (HS-ESS2-4), (HS-ESS2-6), (HS-ESS3-5) **MP.2** Model with mathematics. (HS-ESS2-4), (HS-ESS2-6) **MP.4** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS2-2), (HS-ESS2-4), (HS-ESS2-6), (HS-ESS3-5) **HSN-Q.A.1** Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS2-4),

address a question or solve a problem. (HS-ESS3-5) **RST.11-12.7** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-ESS2-4) **SL.11-12.5**	(HS-ESS2-6), (HS-ESS3-5) **HSN-Q.A.2** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-2), (HS-ESS2-4), (HS-ESS2-6), (HS-ESS3-5) **HSN-Q.A.3**

Unit 5 – Human Activity & Sustainability

Unit Summary

How do humans depend on Earth's resources and what are the effects of resource acquisition and use?

"Civilization exists by geological consent, subject to change without notice." Will Durant, American Historian (1885-1981)

In this unit students *construct an explanation based on evidence* for how the availability of natural resources, occurrence of natural hazards are connected to human activity. Additionally, while students are exploring this idea they apply scientific and engineering ideas to *design, evaluate, and refine* a device that can be used to minimize the impacts of natural hazards. They create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity, and create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity. They use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity, and evaluate or refine a technological solution that reduces impacts of human activities on natural systems. The crosscutting concepts of *cause and effect, stability and change, systems and system models* are called out as an organizing concept for these disciplinary core ideas.

This unit is based on HS-ESS3-1, HS-ESS3-3, HS-LS4-6, HS-ESS3-4, HS-ESS3-6, and *HS-ETS1-3* (*secondary to HS-ESS3-4*).

[Note: The disciplinary core ideas, science and engineering practices, and crosscutting concepts can be taught in either this course or in a high school chemistry and/or biology/life science course.]

Student Learning Objectives

Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. *[Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]* **(HS-ESS3-1)**

Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] *[Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]* **(HS-ESS3-3)**

(Secondary to HS-ESS3-3) **Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.** *[Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]* **(HS-LS4-6)**

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. *[Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]* (HS-ESS3-4)
Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. *[Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]* (HS-ESS3-6)
Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. (HS-ETS1-3)

Unit Sequence	
Part A: *How are human activities influence the global ecosystem?*	
Concepts	**Formative Assessment**
• Resource vitality has guided the development of human society. • Natural hazards and other geologic events have shaped the course of human history. • Natural hazards and other geologic events have significantly altered the sizes of human populations and have driven human migration. • Empirical evidence is required to differentiate between cause and correlation and make claims about how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activities. • Modern civilization depends on major technological systems. • Changes in climate can affect population or drive mass migration.	*Students who understand the concepts are able to:* • Construct an explanation based on valid and reliable evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. • Use empirical evidence to differentiate between how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Part B: *How might we change habits if we replaced the word "environment" with the word "life support system"?*	
Concepts	**Formative Assessment**
• The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources.	*Students who understand the concepts are able to:* • Create a computational simulation to illustrate the relationships among

• Change and rates of change can be quantified and modeled over very short or very long periods. • Some system changes are irreversible. • Modern civilization depends on major technological systems. • New technologies can have deep impacts on society and the environment including some that are not anticipated. • Scientific knowledge is a result of human endeavors imagination and creativity.	management of natural resources, the sustainability of human populations, and biodiversity. • Quantify and model change and rates of change in the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

Part C: *Is the damage done to the global life support system permanent?*

Concepts	Formative Assessment
• Changes in the physical environment, whether naturally occurring or human induced, have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species. • Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. • Thus sustaining biodiversity so that ecosystems' functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. • Both physical models and computers can be used in various ways to aid the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test ways of solving a problem or to see which one is most efficient or economical, and in making a persuasive presentation to a client about how a given design will meet his or her needs. • Criteria may need to be broken down into simpler ones that can be	*Students who understand the concepts are able to:* • Create or revise a simulation based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations to test a solution to mitigate adverse impacts of human activity on biodiversity. • Use empirical evidence to make claims about the impacts of human activity on biodiversity. • Break down the criteria for the design of a simulation to test a solution for mitigating adverse impacts of human activity on biodiversity into simpler ones that can be approached systematically based on consideration of trade-offs. • Design a solution for a proposed problem related to threatened or endangered species or to genetic variation of organisms for multiple species. • Analyze costs and benefits of a solution to mitigate adverse impacts of human activity on biodiversity.

approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. • New technologies can have deep impacts on society and the environment, including some that were not anticipated. • Analysis of costs and benefits is a critical aspect of decisions about technology.	

Part D: *How can the impacts of human activities on natural systems be reduced?*

Concepts	Formative Assessment
• Scientist and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. • Engineers continuously modify these systems to increase benefits while decreasing costs and risks. • Feedback (negative or positive) can stabilize or destabilize natural systems. • When evaluating solutions, it is important to take into account a range of constraints, including costs, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. • New technologies can have deep impacts on society and the environment, including some that are not anticipated. • Analysis of costs and benefits is a critical aspect of decisions about technology.	*Students who understand the concepts are able to:* • Evaluate or refine a technological solution that reduces impacts of human activities on natural systems based on scientific knowledge and student-generated sources of evidence; prioritize criteria and tradeoff considerations.

Part E: *What are the relationships among earth's systems and how are those relationships being modified due to human activity?*

Concepts	Formative Assessment
• Current models predict that, although future regional climate changes will be complex and will vary, average global temperatures will continue to rise. • The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases are added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. • Through computer simulations and other studies, important discoveries are	*Students who understand the concepts are able to:* • Use a computational representation to illustrate the relationships among Earth systems and how these relationships are being modified due to human activity. • Describe the boundaries of Earth systems. • Analyze and describe the inputs and outputs of Earth systems.

still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. • Criteria may need to be broken down into similar ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. • Human activities can modify the relationships among Earth systems.	

What It Looks Like in the Classroom

Environmental factors have affected human populations over the course of history. Resource availability, natural disasters, and other geologic events have driven global development of societies, sizes of human populations, and human migrations. Student understanding of these relationships could be enhanced by examining and citing evidence from text or other investigations that show correlations between human population distribution and regional availability of resources such as fresh water, fertile soils, and fossils fuels.

Students look for cause-and-effect relationships between human population distribution and resource availability and distinguish between causality and correlation. In developing an explanation for how the availability of natural resources has influenced human activity, students consider, for example, the dependence of large urban populations on the technology required to deliver potable water. An example of the role that technology plays could include the impounding of the Colorado River by the Hoover Dam and the formation of Lake Mead, which provides the water required to support large human populations in an otherwise arid and desert habitat.

Historical accounts of natural disasters (e.g., Krakatoa eruption, American Dust Bowl, Superstorm Sandy, and Hurricane Katrina) resulting human suffering and loss of life could provide empirical evidence of past impacts on human population size and distribution. Previous climate change events (sea level fall and rise, desertification of the Sahara) are studied as examples of natural events that can drive human migrations. Students use evidence from data analysis to make inferences and predictions about the impacts of future climate change and global warming on displacement or migration of humans.

When examining and reporting data, students represent resource availability, natural disasters, and human activity symbolically and determine what quantitative relationships exist. Students map these relationships in graphs, charts, or other descriptive models, while considering any limitations on measurement when reporting quantities.

In this unit we also turn our attention to how humans depend on the living world for resources and other benefits provided by biodiversity. Students must know that the sustainability of human societies and the biodiversity that supports them require responsible management of natural resources. Change and rates of change in biodiversity and environmental conditions are quantified and modeled by students over short and long periods of time. Students keep in mind that some system changes are irreversible. Deforestation of tropical rain forests and desertification of grasslands are examples of changes for student research. In their research, students synthesize information from multiple sources and evaluate claims about the impacts of human activity on biodiversity based on analysis of evidence.

Students learn that natural and anthropogenic changes in the physical environment contribute to changes in biodiversity. Changes may include species expansion, invasive species, and extinction. Because humans depend on the living world for resources and other benefits provided by biodiversity, adverse human activities such as overpopulation, exploitation of resources, habitat destruction, pollution, introduction of invasive species, and human impact on climate change must be addressed. Students understand that sustaining biodiversity is critical to maintaining functional ecosystems. Students collect data on growth patterns (exponential, logistic) and carrying capacity using, for example, bacterial populations in a petri dish, status of local fish and mollusk populations in Narragansett Bay, erosion of eel grass beds, or continued Quonset Point dredging. Data could also be collected on Asian Shore Crab infestation and competition with local crabs, or the negative effect of warming coastal estuary water temperature on flounder reproduction rates. Students use data to make informed decisions about how environmental issues affect their communities politically, economically, and ecologically.

Students use data collected to model changes in marine animal populations to better understand the relationship between management of natural resources, biodiversity, and the sustainability of human populations. Students also investigate and research major contributions of scientists and engineers who have developed technologies to produce less pollution and waste in order to prevent ecosystem degradation. Students synthesize information from multiple sources to construct explanations and verify claims about how the environment and biodiversity change and stay the same when affected by human activity.

Students are tasked with designing and evaluating a solution for a proposed problem related to threatened or endangered species. As they consider a design solution, they should know that technological advances by modern civilizations have solved, and sometimes caused, problems related to human interactions with the environment. This relationship could be studied by examining impacts of past technological advances such as electricity generation/distribution, antibiotic production, advanced farming practices, and damming of rivers. This may set the context for a discussion of limits of technological solutions. Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. Students need to determine long- and short-terms goals of a potential solution, while considering that new technologies can have deep impacts on society and the environment, including some that were not anticipated. For instance, students consider solutions that address the unanticipated negative impact wind farms have on birds, bats, and offshore fishing grounds.

Students use empirical evidence of decreasing bird populations to differentiate between specific causes and effects. Students choose an adverse practice and research solutions to associated problems. They might consider wind turbines, deforestation, waste management, noise pollution, or automobile fuel (hydrogen, electricity, water). Solutions for minimizing adverse effects should account for a range of constraints such as cost, safety, reliability, and aesthetics, as well as social, cultural, and environmental impacts, since practical solutions are more likely to be implemented by society. Students can use physical models and computer simulations to aid in the engineering process, test potential solutions, and refine designs.

As they work, project criteria should be broken down and approached systematically. By evaluating or refining a technological solution, such as alternative energy, that reduces impacts of humans on biodiversity, students should consider the cost, benefits, and risks of systems created by engineers. An example might be modeling a solution for addressing the melting of permafrost and the release of previously trapped methane. Students should analyze data for positive and negative feedback within natural systems to predict if there would be stabilization or destabilization of greenhouse gas concentrations. When evaluating solutions, students need to take into account a range of constraints, including costs, safety, and reliability, as well as social, cultural, and environmental impacts.

Modern civilization depends on major technological systems. New technologies can have deep impacts on society and the environment, both anticipated and unanticipated. Examples of impacts include extinction of species and loss of habitat. These changes can lead to a decrease in biodiversity. To address these concepts, students create a computational simulation or mathematical model illustrating the relationships among management of natural resources, the sustainability of human populations, and biodiversity. Simulations model change and rates of change in those relationships. When possible, students symbolically and quantitatively represent natural resource management, sustainability of human populations, and biodiversity. Students also map relationships discovered, considering limitations on measurement when reporting quantities or data.

When evaluating or refining a technological solution that reduces impacts of human activities on natural systems, such as use of alternative energy sources, students read and integrate multiple sources of information to create a coherent understanding of the problem. In their evaluation, they consider costs, benefits, and risks of systems created by engineers. When evaluating solutions, students take into account a range of constraints, including costs, safety, and reliability, as well as any social, cultural, and environmental impacts. Models created by students are used to illustrate and analyze positive and negative feedback within natural systems that may lead to stabilization or destabilization.

Examples of technologies that might limit future impacts of human activity could be small-scale local efforts or large-scale geoengineering solutions for more global issues. Students research and analyze data regarding the use of fossil fuels to power machines and the quantities and types of pollutants produced. The analysis of data could be used to investigate how alternative energy machines, such as electric- or hydrogen powered cars, could be used to reduce carbon emissions. Students consider the availability of infrastructure, trained technicians, economic constraints, reliability, and other trade-offs, like personal aesthetic preference, in their evaluations or design decisions.

Through computer simulations and other studies, important discoveries are still being made about how the ocean, atmosphere, and biosphere interact and are modified in response to human activities. Students describe the boundaries of Earth's systems by looking at models, data sets, or graphics showing temperatures and currents of the ocean and atmosphere. They identify evidence to support the claim that human activity can modify Earth's systems. When students are investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Students also analyze and describe the inputs and outputs of Earth's systems by researching and investigating the amount of carbon dioxide produced by human activities. In their research, students integrate and evaluate multiple sources of information and verify data when possible. Students then design a solution to decrease the amount of carbon dioxide added by human activity. The design process may need to be broken down into logical steps that can be approached systematically, and decisions about the priority of certain criteria over others should be considered throughout the process.

Students use computational representations of geoscience data to illustrate these relationships and make forecasts about Earth's systems. Students illustrate how relationships are being modified due to human activity by graphing temperature changes over a period of time. Rates of change should be quantified and modeled at different time scales. In symbolic representations of relationships between Earth's systems and human activity, students should consider appropriate quantities and limitations on measurement when reporting data.

Integration of engineering

Performance expectations HS-LS4-6 and HS-ESS3-4 specifically identifies a connection to HS-ETS1-3. Students examine solutions for reducing or mitigating impacts of human activity on the environment and biodiversity. This requires students to evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. To meet this requirement, students will evaluate technological solutions that limit human impacts on natural systems. In their evaluations, students should consider how new technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. Because they are asked to design, evaluate, refine or revise, and finally test a solution, this unit has been identified as an opportunity for students to experience the complete engineering cycle. All HS-ETS1 performance expectations have been included here.

Integration of Physical science

The integration of physical science performance expectation HS-PSS2-3 into performance expectation HS-ESS3-1 connects students to the practical applications of physical science as they assess the impacts of natural hazards and natural disasters on the human-made environment. Refer to the physical science model curriculum for additional ideas on how to bundle these two performance expectations.

Connecting with English language arts/literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence of the availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Use empirical evidence to write an explanation for how the availability of natural resources, occurrence of natural hazards, and changes in climate have

influenced human activity.

- Evaluate data to verify claims about the impacts of human activities on the environment and biodiversity, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- Conduct short as well as more sustained research projects to determine the impacts of human activities on the environment and biodiversity, synthesizing information from multiple sources.
- Synthesize information from a range of sources about the impacts of human activities on the environment and biodiversity into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
- Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on the impacts of human activity on biodiversity and how to mitigate these impacts.
- Conduct short as well as more sustained research projects to determine the impacts of human activity on biodiversity and how to mitigate these impacts.
- Evaluate data presented in diverse formats in order to determine the impacts of human activity on biodiversity and how to mitigate these impacts.
- Evaluate data to verify claims about the impacts of human activities on biodiversity and how to mitigate these impacts.
- Synthesize information from a range of sources into a coherent understanding of the impacts of human activities on biodiversity and how to mitigate these impacts.
- Cite specific textual evidence to support a technological solution that reduces the impacts of human activities on natural systems, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Evaluate the validity of hypotheses, data, analysis, and conclusions in a science or technical text about the impact of human activities on natural systems, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- Integrate and evaluate multiple sources of information presented in diverse formats and media in order to evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- Read multiple sources in order to refine design solutions to reduce impacts of human activities on natural systems and create a coherent understanding of the problem.

Mathematics

- Represent how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity symbolically and manipulate the representing symbols. Make sense of quantities and relationships between availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Use units as a way to understand the relationships between availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity. Choose and interpret units consistently in formulas to determine relationships between availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Choose and interpret the scale and the origin in graphs and data displays representing relationships between availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Define appropriate quantities for the purpose of descriptive modeling of relationships between availability of natural resources, occurrence of natural hazards,

and changes in climate and their influence on human activity.

- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities showing relationships between availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Represent symbolically the relationships among management of natural resources, the sustainability of human populations, and biodiversity, and manipulate the representing symbols. Make sense of quantities and relationships among management of natural resources, the sustainability of human populations, and biodiversity.
- Use a mathematical model to describe the management of natural resources, the sustainability of human populations, and biodiversity. Identify important quantities in relationships among management of natural resources, the sustainability of human populations, and biodiversity, and map their relationships using tools. Analyze these relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Represent symbolically the impacts of human activities on the environment and biodiversity, and manipulate the representing symbols. Make sense of quantities and relationships of the impacts of human activities on the environment and biodiversity
- Use units to understand the impacts of human activities on the environment and biodiversity and to guide the solution of multistep problems to reduce these impacts. Choose and interpret units consistently in formulas to determine the impacts of human activities on the environment and biodiversity. Choose and interpret the scale and origin in graphs and data displays showing impacts of human activities on the environment and biodiversity.
- Define appropriate quantities for the purpose of descriptive modeling of impacts of human activities on the environment and biodiversity.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities showing impacts of human activities on the environment and biodiversity.
- Use a mathematical model to describe the impacts of human activities on the environment and biodiversity. Identify important quantities in the impacts of human activities on the environment and biodiversity and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use a mathematical model to describe a solution to mitigate adverse impacts of human activity on biodiversity. Identify important quantities in the impacts of human activities on the biodiversity and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Represent symbolically the relationships among Earth systems and how these relationships are being modified due to human activity, and manipulate the representing symbols. Make sense of quantities and relationships between Earth systems and human activity.
- Use a mathematical model to describe the relationships among Earth systems and how those relationships are being modified due to human activity. Identify important quantities in human activities and their effects on Earth systems and map their relationships using tools. Analyze these relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand how relationships among Earth systems are being modified by human activity. Choose and interpret units consistently in formulas to determine relationships among them.
- Earth systems and how they are being modified by human activity. Choose and interpret the scale and origin in graphs and data displays representing how human activity modifies relationships among Earth systems.
- Define appropriate quantities for the purpose of descriptive modeling of how the relationships among Earth systems are being modified due to human activity.

- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing relationships among Earth systems and how they are being modified due to human activity.
- Represent impacts of human activities on natural systems symbolically and manipulate the representing symbols. Make sense of quantities and relationships between human activities and natural systems.
- Use units as a way to understand the impacts of human activities on natural systems. Choose and interpret units consistently in formulas to determine the impacts of human activities on natural systems. Choose and interpret the scale and origin in graphs and data displays representing the impacts of human activities on natural systems.
- Define appropriate quantities for the purpose of descriptive modeling of the impacts of human activities on natural systems.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of human activities and their impacts on natural systems.
- Use a mathematical model to describe human activities and their effects on natural systems. Identify important quantities in human activities and their effects on natural systems and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Modifications

(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: All Standards, All Students/Case Studies for vignettes and explanations of the modifications.)

- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA).

Research on Student Learning

Most high school students seem to know that some kind of cyclical process takes place in ecosystems. Some students see only chains of events and pay little attention to the matter involved in processes such as plant growth or animals eating plants. They think the processes involve creating and destroying matter rather than transforming it from one substance to another. Other students recognize one form of recycling through soil minerals but fail to incorporate water, oxygen, and carbon dioxide into matter cycles. Even after specially designed instruction, students cling to their misinterpretations. Instruction that traces matter through the ecosystem as a basic pattern of thinking may help correct these difficulties (NSDL, 2015).

Prior Learning

By the end of Grade 8, students understand that:

Physical science

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.

Life science

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
- Growth of organisms and population increases are limited by access to resources.
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.
- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.
- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.
- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.
- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common.

Thus, the distribution of traits in a population changes.

- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

Earth and space science

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.
- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
- Global movements of water and its changes in form are propelled by sunlight and gravity.
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.
- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.
- Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.
- Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.
- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.
- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.
- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Connections to Other Courses

Physical science

- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules

present.

- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Life science

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
- Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction).
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

Earth and space sciences

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.
- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a

variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.
- The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.
- Resource availability has guided the development of human society.
- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.
- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.
- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.
- Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

Suggested Activities and Samples of Open Education Resources

Cost-Benefit Analysis Primer: Students read this explanation about how cost-benefit analysis is derived and applied in order to apply this model to design solutions related to human sustainability. Students then read the application of CBA to water sanitation.

Carbon Stabilization Wedge: Students play this game in order to evaluate competing design solutions for developing, managing, and utilizing energy resources based on cost-benefit ratios.

One For All: A Natural Resources Game: Identify a strategy that would produce a sustainable use of resources in a simulation game. Draw parallels between the chips used in the game and renewable resources upon which people depend. Draw parallels between the actions of participants in the game and the actions of people or governments in real-world situations.

Building Biodiversity and the PREDICTS project and GLOBIO project: Students explore this website to develop an understanding of how computational models of the impacts on biodiversity are created. Next, they explore Conservation Maps for a global perspective of land use and conservation efforts.

Schoolyard Biodiversity: Students assess the biodiversity in their schoolyards, and apply their model outputs to predict the changes in biodiversity as related to human impacts and the application of sustainable practices.

I=P*A*T Equation and Its Variants: Students read this article to learn how ecological economics models are developed and applied to further understand human impacts on our environment.

National Climate Assessment: Students explore the simulations found at this website in order to create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

Stormwater Calculator or the Water Erosion Prediction Project: Students apply the stormwater runoff calculator to determine the impacts of landuse change, precipitation variations, and other parameters on runoff.

The Bean Game: Exploring Human Interactions with Natural Resources: This activity explores the various influences of human consumption of natural resources over time. (use this as a primer for making a computational model).

NSA Challenge: Recycling for a Cleaner World: Students will develop a strategy to increase recycling and waste diversion for their school.

Land and People: Finding a Balance: This environmental study project allows a group of students to consider real environmental dilemmas concerning water use and provide solutions to these dilemmas.

Reefs at Risk: and NOAA Coral Reefs at Risk: Students access and explore a series of interactive maps displaying coral reef data from around the globe and develop hypotheses related to the impacts of climate change (i.e. increased levels of carbon dioxide in our atmosphere) on coral reef health.

GLOBE Carbon Cycle: Students collect data about their school field site through existing GLOBE protocols of phenology, land cover and soils as well as through new protocols focused on biomass and carbon stocks in vegetation. Students participate in classroom activities to understand carbon cycling at local and global scales. Students expand their scientific thinking through the use of systems models.

Earth: Planet of Altered States: Watch a segment of a NASA video and discuss how the earth is constantly changing.

Planet Earth: Watch a global overview of a different biome or habitat on Earth through multiple episodes.

Appendix A: NGSS and Foundations for the Unit
Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. *[Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]* **(HS-ESS3-1)**
Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] *[Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]* **(HS-ESS3-3)**
(Secondary to HS-ESS3-3) **Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.** *[Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]* **(HS-LS4-6)**
Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. *[Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]* **(HS-ESS3-4)**
Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. *[Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]* **(HS-ESS3-6)**
Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. (HS-ETS1-3)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS3-1) • Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ESS3-4) **Using Mathematics and Computational Thinking** • Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-ESS3-3) • Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6) • Create or revise a simulation of a phenomenon, designed device, process, or system. (HS-LS4-6)	**ESS3.A: Natural Resources** • Resource availability has guided the development of human society. (HS-ESS3-1) **ESS3.B: Natural Hazards** • Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-1) **LS4.C: Adaptation** • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-6, *secondary to HS-ESS3-3*) **ESS3.C: Human Impacts on Earth Systems** • The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3) • Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) **ESS3.D: Global Climate Change** • Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1), (HS-LS4-6) **Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-ESS3-6) **Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system. (HSESS3-4), (HS-LS4-6) • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-3) - - - - - - - - - - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • Modern civilization depends on major technological systems. (HS-ESS3-3) • Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-ESS3-4) • New technologies can have deep impacts on

	to human activities. (HS-ESS3-6) **ESS2.D: Weather and Climate** • Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (*secondary to HS-ESS3-6*) **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (*secondary to HS-ESS3-4*)	society and the environment, including some that were not anticipated. (HS-ESS3-3) - ***Connections to Nature of Science*** **Science is a Human Endeavor** • Science is a result of human endeavors, imagination, and creativity. (HS-ESS3-3)

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS3-1),(HS-ESS3-4) **RST.11-12.1** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ESS3-4), (HS-ETS1-3) **RST.11-12.8** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **RST.11-12.7** (HS-ETS1-3) Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. **RST.11-12.9** (HS-ETS1-3). Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS3-	Reason abstractly and quantitatively. (HS-ESS3-1),(HS-ESS3-3),(HS-ESS3-4),(HS-ESS3-6),(HS-ETS1-3) **MP.2** Model with mathematics. (HS-ESS3-3),(HS-ESS3-6),(HS-ETS1-3) **MP.4** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS3-1),(HS-ESS3-4),(HS-ESS3-6) **HSN-Q.A.1** Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS3-1),(HS-ESS3-4),(HS-ESS3-6) **HSN-Q.A.2** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS3-1),(HS-ESS3-4),(HS-ESS3-6) **HSN-Q.A.3**

1) **WHST.9-12.2** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS4-6) **WHST.9-12.5** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS4-6) **WHST.9-12.7**	

Unit 6 – Human Activity & Energy

Unit Summary

How is energy generated for human activity?

In this unit of study, students *engage in argument from evidence, develop and use models, ask questions and define problems, construct explanations and design solutions,* and *evaluate information*. This unit focuses on the physics core ideas surrounding energy and energy transformations as related to the Earth System core idea of energy needs for human activity. Students create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. They apply engineering design principles to design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. Within this unit students also apply the core ideas of related to the behavior of electromagnetic energy to evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. They develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction (*secondary concept*). They apply these core ideas to communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. At the basis of our energy needs is the need for resources to create energy, and therefore students evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. The crosscutting concepts of *systems and system models, energy and matter, cause and effect,* and *stability and change* are called out as an organizing concept for these disciplinary core ideas.

This unit is based on HS-ESS3-2, HS-PS3-1, HS-PS3-2, HS-PS3-3, *HS-PS3-5* (secondary to HS-PS3-3), HS-PS4-3, and HS-PS4-5.

[Note: The disciplinary core ideas, science and engineering practices, and crosscutting concepts can be taught in either this course or in a high school physics course.]

Student Learning Objectives

Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. *[Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]* **(HS-ESS3-2)**

Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. *[Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]* **(HS-PS3-1)**

Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). *[Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]* **(HS-PS3-2)**

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* *[Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency. Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]* **(HS-PS3-3)**
(Secondary to HS-PS3-3) **Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** *[Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]* **(HS-PS3-5)**
Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. *[Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.]* [Assessment Boundary: Assessment does not include using quantum theory.] **(HS-PS4-3)**
Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.* *[Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]* **(HS-PS4-5)**

Part A: *What is the best energy source for a home? How would I meet the energy needs of a house of the future?*

Concepts	Formative Assessment
• All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. • Models can be used to simulate systems and interactions, including energy, matter, and information flows, within and between systems at different scales. • Engineers continuously modify design solutions to increase benefits while decreasing costs and risks. • Analysis of costs and benefits is a critical aspect of decisions about technology. • Scientific knowledge indicates what can happen in natural systems, not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. • New technologies can have deep impacts on society and the environment,	*Students who understand the concepts are able to:* • Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost benefit ratios, scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, and ethical considerations). • Use models to evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios, scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, and ethical considerations).

including some that were not anticipated. • Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. • Many decisions are made not using science alone, but instead relying on social and cultural contexts to resolve issues.	

Part B: *How can we use mathematics in decision-making about energy resources?*

Concepts	Formative Assessment
• That there is a single quantity called energy is due to the fact that a system's total energy is conserved even as, within the system, energy is continually transferred from one object to another and between its various possible forms. • Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • The availability of energy limits what can occur in any system. • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximation inherent in models. • Science assumes that the universe is a vast single system in which basic laws are consistent.	*Students who understand the concepts are able to:* • Use basic algebraic expressions or computations to create a computational model to calculate the change in the energy of one component in a system (limited to two or three components) when the change in energy of the other component(s) and energy flows in and out of the system are known. • Explain the meaning of mathematical expressions used to model the change in the energy of one component in a system (limited to two or three components) when the change in energy of the other component(s) and out of the system are known.

Part C: *I have heard about it since kindergarten but what is energy?*

Concepts	Formative Assessment
• Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy	*Students who understand the concepts are able to:* • Develop and use models based on evidence to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects). • Develop and use models based on evidence to illustrate that energy cannot be created or destroyed. It only moves between one place and another

associated with the configuration (relative position of the particles). • In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles). • Radiation is a phenomenon in which energy stored in fields moves across spaces. • Energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems.	place, between objects and/or fields, or between systems. • Use mathematical expressions to quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compressions of a spring) and how kinetic energy depends on mass and speed. • Use mathematical expressions and the concept of conservation of energy to predict and describe system behavior.

Part D: *Superstorm Sandy devastated the New Jersey Shore and demonstrated to the public how vulnerable our infrastructure is. Using your understandings of energy, design a low technology system that would insure the availability of energy to residents if catastrophic damage to the grid occurs again.*

Concepts	Formative Assessment
• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. • News technologies can have deep impacts on society and the environment, including some that were not anticipated. • Analysis of costs and benefits is a critical aspect of decisions about technology. • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water or for energy sources that minimize pollution that can be addressed through engineering. These global challenges also may have	*Students who understand the concepts are able to:* • Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. • Analyze a device to convert one form of energy into another form of energy by specifying criteria and constraints for successful solutions. • Use mathematical models and/or computer simulations to predict the effects of a device that converts one form of energy into another form of energy.

manifestations in local communities.	

Part E: *How can electromagnetic radiation be both a wave and a particle at the same time?*

Concepts	Formative Assessment
• Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. • Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. • A wave model or a particle model (e.g., physical, mathematical, computer models) can be used to describe electromagnetic radiation—including energy, matter, and information flows—within and between systems at different scales. • A wave model and a particle model of electromagnetic radiation are based on a body of facts that have been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.	*Students who understand the concepts are able to:* • Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model and that for some situations one model is more useful than the other. • Evaluate experimental evidence that electromagnetic radiation can be described either by a wave model or a particle model and that for some situations one model is more useful than the other. • Use models (e.g., physical, mathematical, computer models) to simulate electromagnetic radiation systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Part F: *How does the International Space Station power all of its equipment? How do astronauts communicate with people on the ground?*

Concepts	Formative Assessment
• Solar cells are human-made devices that capture the sun's energy and produce electrical energy. • Photoelectric materials emit electrons when they absorb light of a high enough frequency. • Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. • Criteria and constraints also include satisfying any requirements set by	*Students who understand the concepts are able to:* • Communicate qualitative technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. • Communicate technical information or ideas about technological devices that use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy in multiple formats (including orally, graphically, textually, and mathematically). • Analyze technological devices that use the principles of wave behavior and wave interactions with matter to transmit and capture information

society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food and for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. • Wave interaction with matter systems can be designed to transmit and capture information and energy. • Science and engineering complement each other in the cycle known as research and development (R&D). • Modern civilization depends on major technological systems. • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.	and energy by specifying criteria and constraints for successful solutions. • Evaluate a solution offered by technological devices that use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

What it Looks Like in the Classroom

In this unit, students explore the disciplinary core ideas around energy resources while applying core ideas from physical science related to energy. Working from the premise that all forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs, risks, and benefits, students use cost–benefit ratios to evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources. For example, students might investigate the real-world technique of using hydraulic fracturing to extract natural gas from shale deposits versus other traditional means of acquiring energy from natural resources. Students will synthesize information from a range of sources into a coherent understanding of competing design solutions for extracting and utilizing energy and mineral resources. As students evaluate competing design solutions, they should consider that new technologies could have deep impacts on society and the environment, including some that were not anticipated. Some of these impacts could raise ethical issues for which science does not provide answers or solutions. In their evaluations, students should make sense of quantities and relationships associated with developing, managing, and utilizing energy and mineral resources. Mathematical models can be used to explain their evaluations. Students might represent their understanding by conducting a Socratic seminar as a way to present opposing views. Students should consider and discuss decisions about designs in scientific, social, and cultural contexts.

Related to the integration of physical science core ideas, the following classroom methods may be applied; however the big idea centered on our energy resources is in the forefront throughout the unit.

Students will develop an understanding that energy is a quantitative property. They will explore energy in systems as a function of the motion and interactions of matter and radiation within systems. Energy can be detected and measured at the macroscopic scale as the phenomena of motion, sound, light, and thermal energy. Students will also learn that these forms of energy can be modeled in terms of the energy associated with the motion of particles or the energy stored in fields (gravitational, electric, magnetic,) that mediate interactions between particles.

Students are ultimately able to develop models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles, or objects, and energy associated with the relative position of particles, or objects. In some cases, the relative position energy can be thought of as stored in fields. Students should be able to qualitatively show that an object in a gravitational field has a greater amount of potential energy as it is put into higher and higher locations in that field. An example of this could be investigating how an object, such as a ball, when released from successively higher and higher positions hits the ground at greater and greater velocities (kinetic energy).

Kinetic Energy	$KE = \frac{1}{2}mv^2$
Potential Energy	$PE_{gravitational} = mgh$
Work	$W = Fd$

In these kinds of investigations, students should understand how to obtain the original potential energy of the object. They should know that when work is done on an object, the energy of the object changes, such as when the wrecking ball of a demolition machine is raised. Work can be calculated ($W=Fd$), appreciated, and understood as a concept. Students should recognize the relationship between the work done on an object and the potential energy of objects. Considering an object that collides with the ground, students should be able to list a variety of ways the kinetic energy is transferred upon impact. For example, kinetic energy is transferred to thermal energy or to sound. Emphasis on the law of conservation of energy should be evident at all points of this discussion. Energy cannot be created or destroyed. It only moves between one place and another, between objects and/or fields, or between systems. Students should demonstrate their understanding of energy conservation and transfer using models. Models should be evidence based and illustrate the relationship between energy at the bulk scale and motion and position at the particle scale. Models should also illustrate conservation of energy. Examples of models might include diagrams, drawings, written descriptions, or computer simulations. Modeling should include strategic use of digital media in presentations to enhance understanding.

Students should understand that changes of energy in a system are described in terms of energy flows into, out of, and within the system. They should also be able to describe the components of a system. Basic algebraic expressions or computations should be used to model the energy of one component of a system (limited to two or three components) when the change in energy of the other components is known. At this point, the law of conservation of energy should be evident numerically through analysis of calculated data.

Students also should use mathematical expressions to quantify how stored energy in a system depends on configuration—for example, the stretching or compression of a spring. Students might calculate the potential energy of springs. Students should also consider how stored energy depends on configuration in terms of relative positions of charged particles. Students might perform investigations with capacitors. They should also know that the availability of energy limits what can occur in any system.

Another way for students to illustrate that, in systems, energy can be transformed into various types of energy (both potential and kinetic) is to describe and diagram the changes in energy that occur in systems. For example, students could diagram steps showing the transformations of energy that occur when a student uses a yo-yo or the transformations of energy that occur in a burning candle. Ultimately, students might also diagram the steps showing transformations of energy, from fusion in the sun to the food that we eat. Students should include the phenomenon of radiation, in which energy stored in fields can move across spaces, when appropriate.

In this unit, students will also design, build, and refine a device that works within given constraints to convert one form of energy into another based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. They should also use mathematical models or computer simulations to predict the effects of a device that converts one form of energy into another.

To fulfill the engineering component of this unit as described above, students might be assigned an energy project to explore energy transformation and conservation. This could be a computer simulation, practical model, or model with Excel-calculated formulae to verify expected results. Students could also design and build a Rube Goldberg apparatus to perform a given task. After conducting research, students could make claims or defend arguments about various green energy sources. Properties of dams, solar cells, solar ovens, generators, and turbines could be explored through simulations. Evaluations of devices should be both qualitative and quantitative, and analysis of costs and benefits is a critical aspect of design decisions.

When focusing on engineering, students keep in mind that modern civilization depends on major technological systems, and that engineers continuously modify these systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. Students should also develop an understanding that new technologies can have deep impacts on society and the environment, including some that were not anticipated.

The suggested methods that follow focus on the PE's related to waves and electromagnetic energy.

Students are then introduced to the idea that electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Students should have an understanding of the wave model from their work in the previous unit. Because all observations cannot be explained with one model, students should explore the wave and particle models and make determinations about which is most appropriate in which situations. Students might begin the unit by exploring the history of the wave and particle models. In their research, students should evaluate the hypotheses, data, analysis, and conclusions in text and cite evidence to support their analysis. Students should also be able to support claims, evidence, and reasoning with mathematical expressions representing wave and particle models of electromagnetic radiation, rearranging formulas to highlight a quantity of interest, and making sense of quantities and relationships.

Students must be able to determine which model is most appropriate under which circumstances by evaluating experimental evidence, claims, evidence, and reasoning. Students may research this question and present their findings in an argumentative essay. Students might consider particular phenomena, such as diffraction, and determine whether the wave or particle model provides the best explanation. Using a Venn diagram, students could differentiate between phenomena and models. Students use models (e.g., physical, mathematical, computer models) to simulate electromagnetic radiation systems and interactions.

Some **wave** applications include:

- Diffraction—Students can be shown how waves bend around obstacles in a wave tank or explore using a prism and a laser.
- Polarization—Students could explore this phenomenon through its use in 3D movies, computer monitors, cell phones, and sunglasses.
- Doppler shift—Students can consider applications of Doppler shift in astronomy and weather.
- Wave interference—A wave tank or computer simulation could be used to illustrate interference.
- Transmission—Wave transmission can be modeled using computer simulations.

Some **particle** applications include:

- Refraction—Students can explore light bending as changes in media using prisms or water. They can also use Snell's Law to describe the relationship between angles of incidence and refraction.
- Reflection—Students should develop an understanding of incident rays and reflected rays using the law of reflection. They might explore this concept using a wave tank.

- Ray diagrams—Students can create lens ray diagrams on paper.
- Photoelectric effect—Students can explore solar cells to understand this phenomenon. Note that if this course is sequenced before chemistry, students will not have an understanding of electrons.
- Piezoelectric effect—Students might research this phenomenon using solar cells and ultrasound analogies.

Students understand that the energy in a wave depends on its frequency as well as its amplitude (energy is proportional to amplitude squared). Different frequencies of electromagnetic radiation also have different abilities to penetrate matter. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. For example ultraviolet light penetrates the skin and can cause skin cancer, while X-rays and gamma rays can permeate deep tissue and cause radiation poisoning. Students should explore these cause-and-effect relationships through an investigation of scientific text. They should cite evidence from multiple sources; evaluate hypotheses, data, analysis, and conclusions; and assess strengths and limitations.

To explore color and energy, students could explore Herschel's experiment in which thermometers were placed in different colors to see which color was "hottest." It turned out that Herschel's control, placed in what is now known as infrared, was the hottest of all. This demonstrated that there are wavelengths of electromagnetic radiation beyond the visible spectrum.

Students research how different spectra of light interact with matter, such as the effects of electromagnetic radiation on the human body—effects of nuclear disasters on plant workers (Chernobyl, Fukushima, Three Mile Island), skin cancer, medical X-rays, diagnostic imaging technology, etc. Specifically, they should evaluate the validity and reliability of source material and determine cause-and-effect relationships. The final product could be a written essay, presentation, model, or oral debate. Research topics might include:

The engineering component of this unit includes exploring how technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. Students might investigate solar cells and how they work, including a qualitative description of the photoelectric effect. Photoelectric materials emit electrons when they absorb light of a high enough frequency. This is another opportunity to discuss solar cells. Other technologies that use the photoelectric effect include automatic doors, safety lights, television camera tubes, light-activated counters, intrusion alarms, and streetlights.

Students evaluate the efficiency and cost-effectiveness of modern solar cell technology. Given existing solar cells, students may consider how they rate in terms of one-time purchase, aesthetics, maintenance, and overall total cost of ownership. They evaluate this energy solution scientific knowledge, student- generated sources of evidence, prioritized criteria, and tradeoff considerations.

The advantages and disadvantages of various electromagnetic frequencies in modern technology are explored using examples such as astronomical telescopes (microwave, infrared, visible, etc.), LiDAR, solar panel cells, CDs, Blu-ray, infrared remote controls or car fobs, infrared motion detection cameras, computer memory storage, or fiber optics. Students create models of the interactions in these common types of systems and explain their model using either written or oral media.

Integration of engineering-

Students communicate technical information comparing energy resources while integrating their knowledge of physical science and energy transformations. ETS1-1 and ETS1-3 are identified as appropriate connections so that students can analyze a major global challenge and evaluate a solution to a complex real-world problem.

Integration of PE's and DCI's from other units-

This unit ties in with the physical science model curriculum units on energy (Unit 4) and on waves (Unit 7) as they pertain to energy resources. Refer to those units for additional classroom integration methods. Additionally, consider linking the performance expectation related to nuclear energy with this unit (HS-PS1-8).

Leveraging English Language Arts/Literacy and Mathematics

English Language Art/Literacy

- Collect relevant data across a broad spectrum of sources about the distribution of energy in a system and assess the strengths and limitations of each source.
- Synthesize findings from experimental data into a coherent understanding of energy distribution in a system.
- Cite specific textual evidence to evaluate competing design solutions for developing, managing, and utilizing energy resources based on cost–benefit ratios.
- Evaluate the hypotheses, data, analysis, and conclusions of competing design solutions for developing, managing, and utilizing energy resources based on cost–benefit ratios, verifying the data when possible and corroborating or challenging conclusions with other design solutions.
- Integrate and evaluate multiple design solutions for developing, managing, and utilizing energy resources based on cost–benefit ratios in order to reveal meaningful patterns and trends.
- Evaluate the hypotheses, data, analysis, and conclusions of competing design solutions for developing, managing, and utilizing energy resources based on cost–benefit ratios, verifying the data when possible and corroborating or challenging conclusions with other design solutions.
- Synthesize data from multiple sources of information in order to create data sets that inform design decisions and create a coherent understanding of developing, managing, and utilizing energy resources.
- Make strategic use of digital media in presentations to enhance understanding of the notion that energy is a quantitative property of a system and that the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Make strategic use of digital media in presentations to support the claim that energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects).
- Conduct short as well as more sustained research projects to describe energy conversions as energy flows into, out of, and within systems.
- Integrate and evaluate multiple sources of information presented in diverse formats and media to describe energy conversions as energy flows into, out of, and within systems.
- Evaluate scientific text regarding energy conversions to determine the validity of the claim that although energy cannot be destroyed, it can be converted into less useful forms.
- Assess the extent to which the reasoning and evidence in a text supports the author's claim that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.
- Cite specific textual evidence to support the wave model or particle model in describing electromagnetic radiation, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text relating that electromagnetic radiation can be described either by a wave model or a particle model and that for some situations one model is more useful than the other, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

- Assess the extent to which the reasoning and evidence in a text describing the effects that different frequencies of electromagnetic radiation have when absorbed by matter support the author's claim or recommendation.
- Cite textual evidence to support analysis of science and technical texts describing the effects that different frequencies of electromagnetic radiation have when absorbed by matter, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., qualitative data, video multimedia) in order to address the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text describing the effects that different frequencies of electromagnetic radiation have when absorbed by matter, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- Gather relevant information from multiple authoritative print and digital sources describing the effects that different frequencies of electromagnetic radiation have when absorbed by matter, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- Write informative/explanatory texts about technological devices that use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy, including the narration of scientific procedures, experiments, or technical processes.
- Integrate and evaluate multiple sources of information about technological devices that use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy, presented in diverse formats and media (e.g., quantitative data, video, multimedia), in order to address a question or solve a problem.

Mathematics

- Use a mathematical model to describe energy distribution in a system when two components of different temperature are combined. Identify important quantities in energy distribution in a system when two components of different temperature are combined and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of the properties of water and their effects on Earth materials and surface processes.
- Use symbols to represent an explanation of the best of multiple design solutions for developing, managing, and utilizing energy and mineral resources and manipulate the representing symbols. Make sense of quantities and relationships in cost–benefit ratios for multiple design solutions for developing, managing, and utilizing energy and mineral resources symbolically and manipulate the representing symbols.
- Use a mathematical model to explain the evaluation of multiple design solutions for developing, managing, and utilizing energy and mineral resources. Identify important quantities in cost–benefit ratios for multiple design solutions for developing, managing, and utilizing energy and mineral resources and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Represent symbolically an explanation about the notion that energy is a quantitative property of a system and that the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known, and manipulate the representing symbols. Make sense of quantities and relationships about the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known symbolically, and manipulate the representing symbols.
- Use a mathematical model to explain the notion that energy is a quantitative property of a system and that the change in the energy of one component in a

system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known. Identify important quantities in energy of components in systems and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

- Use units as a way to understand how the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known; choose and interpret units consistently in formulas representing how the change in the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known; choose and interpret the scale and the origin in graphs and data displays representing that the energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Represent the conversion of one form of energy into another symbolically, considering criteria and constraints, and manipulate the representing symbols. Make sense of quantities and relationships in the conversion of one form of energy into another.
- Use a mathematical model of how energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects). Identify important quantities representing how the energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects), and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use a mathematical model to describe the conversion of one form of energy into another and to predict the effects of the design on systems and/or interactions between systems. Identify important quantities in the conversion of one form of energy into another and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand the conversion of one form of energy into another; choose and interpret units consistently in formulas representing energy conversions as energy flows into, out of, and within systems; choose and interpret the scale and the origin in graphs and data displays representing energy conversions as energy flows into, out of, and within systems.
- Define appropriate quantities for the purpose of descriptive modeling of a device to convert one form of energy into another form of energy.
- Represent symbolically that electromagnetic radiation can be described either by a wave model or a particle model and that for some situations one model is more useful than the other, and manipulate the representing symbols.
- Make sense of quantities and relationships between the wave model and the particle model of electromagnetic radiation.
- Interpret expressions that represent the wave model and particle model of electromagnetic radiation in terms of the usefulness of the model depending on the situation.
- Choose and produce an equivalent form of an expression to reveal and explain properties of electromagnetic radiation.
- Rearrange formulas representing electromagnetic radiation to highlight a quantity of interest, using the same reasoning as in solving equations.
- Represent the principles of wave behavior and wave interactions with matter to transmit and capture energy symbolically, considering criteria and constraints, and manipulate the representing symbols. Make sense of quantities and relationships in the principles of wave behavior and wave interactions with matter to transmit and capture energy.
- Use a mathematical model to describe the principles of wave behavior and wave interactions with matter to transmit and capture information and energy and to predict the effects of the design on systems and/or interactions between systems. Identify important quantities in the principles of wave behavior and wave

interactions with matter to transmit and capture information and energy, and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Modifications

(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: All Standards, All Students/Case Studies for vignettes and explanations of the modifications.)

- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA).

Research on Student Learning

Students rarely think energy is measurable and quantifiable. Students' alternative conceptualizations of energy influence their interpretations of textbook representations of energy.

Students tend to think that energy transformations involve only one form of energy at a time. Although they develop some skill in identifying different forms of energy, in most cases their descriptions of energy-change focus only on forms which have perceivable effects. The transformation of motion to heat seems to be difficult for students to accept, especially in cases with no temperature increase. Finally, it may not be clear to students that some forms of energy, such as light, sound, and chemical energy, can be used to make things happen.

The idea of energy conservation seems counterintuitive to students who hold on to the everyday use of the term energy, but teaching heat dissipation ideas at the same time as energy conservation ideas may help alleviate this difficulty. Even after instruction, however, students do not seem to appreciate that energy conservation is a useful way to explain phenomena. A key difficulty students have in understanding conservation appears to derive from not considering the appropriate system and environment. In addition, high-school students tend to use their conceptualizations of energy to interpret energy conservation ideas. For example, some students interpret the idea that "energy is not created or destroyed" to mean that energy is stored up in the system and can even be released again in its original form. Or, students may believe that no energy remains at the end of a process, but may say that "energy is not lost" because an effect was caused during the process (for example, a weight was lifted). Although teaching approaches which accommodate students' difficulties about energy appear to be more successful than traditional science instruction, the main deficiencies outlined above remain despite these approaches (NSDL, 2015)

Prior Learning

Physical science

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).
- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- A system of objects may also contain stored (potential) energy, depending on their relative positions.
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.
- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.
- A sound wave needs a medium through which it is transmitted.
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Life Science

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
- Growth of organisms and population increases are limited by access to resources.
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.
- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

Earth and space science

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.
- Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.
- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.
- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Connections to Other Courses
Physical science • Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. • A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. • Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. • In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. • The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. • Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. • The availability of energy limits what can occur in any system. • Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.
- The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.

Life science

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

Earth and space science

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.
- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.
- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

- Resource availability has guided the development of human society.
- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

Suggested Activities and Samples of Open Education Resources for this Unit
Carbon Stabilization Wedge: Students play this game in order to evaluate competing design solutions for developing, managing, and utilizing energy resources based on cost-benefit ratios.
One For All: A Natural Resources Game: Identify a strategy that would produce a sustainable use of resources in a simulation game. Draw parallels between the chips used in the game and renewable resources upon which people depend. Draw parallels between the actions of participants in the game and the actions of people or governments in real-world situations.
National Climate Assessment: Students explore the simulations found at this website in order to create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
Know Your Energy Costs: The goal of this activity is to become aware of how much energy you use at school — and the financial and environmental costs.
Earth: Planet of Altered States: Watch a segment of a NASA video and discuss how the earth is constantly changing.
Climate Reanalyzer: Students use the Environmental Change Model of the Climate Reanlyzer to study the feedbacks in the climate system.
Energy Skate Park: Basics: Learn about conservation of energy with a skater gal! Explore different tracks and view the kinetic energy, potential energy and friction as she moves. Build your own tracks, ramps, and jumps for the skater.
Work and Energy Workbook Labs: The lab description pages describe the question and purpose of each lab and provide a short description of what should be included in the student lab report.
Build a Solar House: Construct and measure the energy efficiency and solar heat gain of a cardboard model house. Use a light bulb heater to imitate a real furnace and a temperature sensor to monitor and regulate the internal temperature of the house. Use a bright bulb in a gooseneck lamp to model sunlight at different times of the year, and test the effectiveness of windows for passive solar heating.
Energy Skate Park: Basics: Learn about conservation of energy with a skater gal! Explore different tracks and view the kinetic energy, potential energy and friction as she moves. Build your own tracks, ramps, and jumps for the skater.
Work and Energy Workbook Labs: The lab description pages describe the question and purpose of each lab and provide a short description of what should be included in the student lab report.
Introduction to the Electromagnetic Spectrum: NASA background resource
Technology for Imaging the Universe: NASA background resource
NASA LAUNCHPAD: Making Waves: NASA e-Clips activity on the electromagnetic spectrum
Radio Waves and Electromagnetic Fields: Phet simulation demonstrating wave generation, propagation and detection with antennas.
Refraction: https://phet.colorado.edu/en/simulation/wave-interferencePHeT simulation addressing refraction of light at an interface.

Wave Interference: Phet simulation of both mechanical and optical wave phenomena
Thin Film Interference: OSP simulation of thin film interference for various wavelengths of visible light
Photoelectric Effect Phet: Phet simulation addressing evidence for particle nature of electromagnetic radiation
Photoelectric Effect OSP: Open Source Physics simulation of the photoelectric effect.
Interaction of Molecules with Electromagnetic Radiation: Phet simulation exploring the effect of microwave, infrared, visible and ultraviolet radiation on various molecules.
Wave/Particle Dualism: Phet simulation of wave and particle views of interference phenomena.
X-ray Technology: OSP Simulation of optimization of X-ray contrast by varying energy of X-rays, materials characteristics and measurement parameters

Appendix A: NGSS and Foundations for the Unit
Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. *[Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]* **(HS-ESS3-2)**
Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. *[Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]* **(HS-PS3-1)**
Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). *[Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]* **(HS-PS3-2)**
Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* *[Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency. Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]* **(HS-PS3-3)**
(Secondary to HS-PS3-3) **Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** *[Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]* **(HS-PS3-5)**
Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. *[Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.]* [Assessment Boundary: Assessment does not include using quantum theory.] **(HS-PS4-3)**
Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.* *[Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]* **(HS-PS4-5)**

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems • Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-2) **Developing and Using Models** • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2), (HS-PS3-5) **Using Mathematics and Computational Thinking** • Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1) **Constructing Explanations and Designing Solutions** • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS3-3) **Engaging in Argument from Evidence** • Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-PS4-3) • Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (HS-ESS3-2)	**ESS3.A: Natural Resources** • All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2) **PS3.A: Definitions of Energy** • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-2) • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)	**Cause and Effect** • Systems can be designed to cause a desired effect. (HS-PS4-5) • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS3-5) **Systems and System Models** • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (HS-PS3-1) • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-PS4-3) **Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS3-3) • Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2) - ***Connections to Engineering, Technology, and Applications of Science***

Obtaining, Evaluating, and Communicating Information

- Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS4-5)

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. *(secondary to HS-ESS3-2)*

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)

Science is a Human Endeavor

- Science is a result of human endeavors, imagination, and creativity. (HS-ESS3-3)

Science Addresses Questions About the Natural and Material World

- Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-2)
- Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-

PS3.B: Conservation of Energy and Energy Transfer

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1)
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1)
- The availability of energy limits what can occur in any system. (HS-PS3-1)

PS3.D: Energy in Chemical Processes

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3)

PS3.C: Relationship between Energy and Forces

- When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5, secondary to HS-PS3-3)

PS4.A: Wave Properties

- Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a

Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5)

Influence of Science, Engineering and Technology on Society and the Natural World

- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3), (HS-PS4-5)
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-ESS3-2)
- Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS3-2)

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment. The science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-PS4-3)

2) • Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-ESS3-2)	location in different directions without getting mixed up.) (HS-PS4-3) • Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-5) **PS4.B: Electromagnetic Radiation** • Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3) • Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5) **PS3.D: Energy in Chemical Processes** • Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary to HS-PS4-5)	

Embedded English Language Arts /Literacy	Mathematics
Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS4-3), (HS-ESS3-2) **RST.11-12.1** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-PS4-3),(HS-ESS3-2) **RST.11-12.8** Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-3), **RST.9-10.8** Write informative/explanatory texts, including the narration of historical events,	Reason abstractly and quantitatively. (HS-ESS3-2), (HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-5), (HS-PS4-3) **MP.2** Model with mathematics. (HS-PS3-1), (HS-PS3-2), (HS-PS3-3), (HS-PS3-5) **MP.4** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1),(HS-PS3-3) **HSN-Q.A.1** Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1),(HS-PS3-3) **HSN-Q.A.2** Choose a level of accuracy appropriate to limitations on measurement when

scientific procedures/experiments, or technical processes. (HS-PS4-5) **WHST.11-12.2** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-5) **WHST.9-12.7** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-5) **WHST.11-12.8** Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-5) **WHST.9-12.9** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1),(HS-PS3-2),(HS-PS3-5) **SL.11-12.5**	reporting quantities. (HS-PS3-1),(HS-PS3-3) **HSN-Q.A.3** Interpret expressions that represent a quantity in terms of its context. (HS-PS4-3) **HSA-SSE.A.1** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-3) **HSA-SSE.B.3** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-3) **HAS.CED.A.4**