Unit 1: Evidence of a Common Ancestry

Instructional Days: 15

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)**

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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.
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
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
LS4.A	The collection of fossils and their placement in chronological order is known as the fossil record
LS4.B	Natural selection leads to the predominance of certain traits in a population, and the suppression of others
LS4.C	Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions

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Quick Links		

Enduring Understandings
• 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. (MSLS41) • 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.
Essential Questions
• How do we know that evolution occurs? • How do populations change over time?

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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.

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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.

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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 organisms.	*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.

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What It Looks Like in the Classroom
Prior to middle school, students know that some living organisms resemble organisms that once lived on Earth. Fossils provide evidence about the types of organisms and environments that existed long ago. In this unit of study, students will build on this knowledge by examining how the fossil record documents the existence, diversity, extinction, and change of many life forms through Earth's history. The fossil record and comparisons of anatomical similarities between organisms and their embryos enable the inference of lines of evolutionary descent. Students analyze images or data to identify patterns in the locations of fossils in layers of sedimentary rock. They can use their understanding of these patterns to place fossils in chronological order. Students may make connections between their studies of plate movement in grade 7 and the possible shifting of layers of sedimentary rock to explain inconsistencies in the relative chronological order of the fossil record as it is seen today. Students can analyze data on the chronology of the fossil record based on radioactive dating. An explanation of radioactive dating can be provided to students along with data, but students are not expected to complete any calculations. Information can be provided in the form of data tables correlating fossil age with half-life. This information could also be presented in the form of a graph. Students may analyze images from the fossil record to identify patterns of change in the complexity of the anatomical structures in organisms. For example, students can observe pictures of fossilized organisms with similar evolutionary histories in order to compare and contrast changes in their anatomical structures over time. Students may be placed in groups, with each group examining changes in anatomical structures over time within one evolutionary lineage (e.g., the whale, the horse, cycads). Once students have identified patterns of change within one evolutionary lineage, they can meet with students from other groups to discuss patterns of change across multiple evolutionary lineages. Students could then present their findings using a variety of media choices (PowerPoint, poster, short skit or play, comic strip, etc.). This activity would provide application of the real-world phenomenon that life on Earth changes over time. Students could be provided with multimedia experiences in order to analyze visual displays of the embryological development of different species. They can analyze the linear and nonlinear relationships among the embryological developments of different species. For example, students can analyze data about embryological development to determine whether development across species shares a similar rate, similar size of embryos, or similar characteristics over a period of time. If these characteristics are consistent across species, a linear relationship can be inferred. At the point where the rate, size, or general characteristics of development diverge, the relationship can then be classified as nonlinear.

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Students can integrate the patterns they identified in the fossil record by studying sedimentary rock images and radioactive dating data provided by the teacher and the relationships they discovered through their study of embryological development with evidence from informational texts to develop an explanation of changes in life forms throughout the history of life on Earth. This explanation could be presented in the form of a claim, with students required to cite evidence from their studies of diagrams, images, and texts to explain that life on Earth has changed over time.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support the analysis of patterns found in the fossil record to document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth.
- Use scientific, precise details in the explanations.
- Integrate quantitative or technical information about the fossil record that is expressed in words into a version of that information expressed visually in the form of a flowchart, diagram, model, graph, or table.
- Attending to the precise details of explanations or descriptions, cite specific textual evidence to support analysis of science texts' information on the relationships between the anatomical similarities and differences among modern organisms and between modern and fossil organisms and their fossil relationships.
- Write informative/explanatory text examining anatomical similarities and differences among modern organisms and between modern and fossil organisms and their fossil relationships. The text should convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
- Draw evidence from informational texts to support an analysis of, reflection on, and research about anatomical similarities and differences among modern organisms and between modern and fossil organisms used to infer evolutionary relationships.
- Engage in a range of collaborative discussions about the anatomical similarities and differences among modern organisms and between modern and fossil organisms used to infer evolutionary relationships. Discussions must provide opportunities for students to clearly express their own ideas and exchange ideas with others. The discussions may be one on one, in groups, or led by the teacher.

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- Present claims and findings to explain the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. Emphasize the important points in a focused, coherent manner with relevant evidence, valid reasoning, and well-chosen details. During the presentation, students must use appropriate eye contact, adequate volume, and clear pronunciation.
- Cite specific textual evidence to support the analysis of pictorial data comparing patterns of similarities in embryological development across multiple species to identify relationships not evident in the fully formed anatomy. Attention must be paid to the precise details of explanation or descriptions.
- Integrate quantitative or technical information about general patterns of relatedness among embryos of different organisms expressed in words in a text with a version expressed in a flowchart, diagram, model, graph, or table.
- Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with the information gained from reading a text about embryological development across multiple species in order to identify relationships not evident in the fully formed anatomy.

Mathematics

- Use variables to represent numbers and write expressions to represent patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearances in the rock record to 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. Understand that a variable can represent an unknown number or, depending on the purpose at hand, any number in a specified set.
- Use variables to represent numbers and write expressions showing patterns that can be used to identify cause-and-effect relationships among the anatomical similarities and differences among modern organisms and between modern and fossil organisms. This representation will be used to infer evolutionary relationships. Understand that a variable can represent an unknown number or, depending on the purpose at hand, any number in a specified set.

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)

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Research on Student Learning
Some research suggests that students' understanding of evolution is related to their understanding of the nature of science and their general reasoning abilities. Findings indicate that students who cannot argue with evidence tend to retain nonscientific beliefs such as "evolutionary change occurs as a result of need" because they fail to examine alternative hypotheses and their predicted consequences, and they fail to comprehend conflicting evidence. Thus, they are left with no alternative but to believe their initial intuitions or the misstatements they hear (NSDL, 2015).

Prior Learning
By the end of Grade 5, students understand that: • Some kinds of plants and animals that once lived on Earth are no longer found anywhere. • Fossils provide evidence about the types of organisms that lived long ago and also about the nature of their environments.

Future Learning
Life science • 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. *Earth and space science* • Continental rocks, which can be more than 4 billion years old, 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.

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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.

Sample of Open Education Resources
NOVA: Judgement Day: Intelligent Design on Trial: Human Chromosome 2: This video segment from NOVA: "Judgment Day: Intelligent Design on Trial" reveals how genetic evidence helped to confirm an important component of Darwin's theory of evolution by natural selection: the common ancestry of humans and apes. In particular, it explains that humans have one fewer chromosome pair in their cells than apes, due to a mutation found in chromosome number 2 that caused two chromosomes to fuse into one. The Day the Mesozoic Died This three-act film tells the story of the detective work that solved the mystery of what caused the disappearance of the dinosaurs at the end of the Cretaceous period. Shot on location in Italy, Spain, Texas, Colorado, and North Dakota, the film traces the uncovering of key clues that led to the discovery that an asteroid struck the Earth 66 million years ago, triggering a mass extinction of animals, plants, and microorganisms.

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)	**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	**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)

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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)	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)	**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)

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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 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**	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**

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Common Vocabulary	
Diversity Life form Sedimentary Chronological order Fossil record History of life	Natural law Anatomical Ancestry Radioactive dating

Unit 2: Selection and Adaptation

Instructional Days: 20

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)**

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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.
MS-LS4-5	Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.
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
LS4.A	The collection of fossils and their placement in chronological order is known as the fossil record
LS4.B	Natural selection leads to the predominance of certain traits in a population, and the suppression of others
LS4.C	Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions

Unit 2: Selection and Adaptation

Instructional Days: 20

Quick Links		

Enduring Understandings
• 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. (MSLS41) • 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.
Essential Questions
• How do we know that evolution occurs? • How do populations change over time?

Unit 2: Selection and Adaptation

Instructional Days: 20

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 2: Selection and Adaptation

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<table>
<tr><th colspan="2">Unit Sequence</th></tr>
<tr><td colspan="2">Part B: How can the environment effect natural selection?</td></tr>
<tr><th>Concepts</th><th>Formative Assessments</th></tr>
<tr><td>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-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.</td><td>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.</td></tr>
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<table>
<tr><th colspan="2">Unit Sequence</th></tr>
<tr><td colspan="2">Part C: Are Genetically Modified Organisms (GMO) safe to eat?</td></tr>
<tr><th>Concepts</th><th>Formative Assessments</th></tr>
<tr><td>• 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.</td><td>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).</td></tr>
</table>

Unit 2: Selection and Adaptation

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What It Looks Like in the Classroom
In this unit of study, students will build on their prior knowledge by constructing explanations that describe how genetic variations increase some individuals' probability of surviving and reproducing. Mathematical representations will be used to support explanations of how natural selection leads to increases and decreases of specific traits in populations over time. Students will analyze numerical data sets that represent a proportional relationship between some change in the environment and corresponding changes in genetic variation over time. Students will summarize these numerical data sets and construct explanations for how the proportional relationship could impact the probability of some individuals surviving and reproducing in a specific environment. Students will construct explanations based on evidence that describes how genetic variations can provide a survival and reproductive advantage over other traits. This evidence could be provided through activities that model these phenomena or by examining and analyzing data from informative texts. Based on their findings, students can write claims about how natural selection leads to a predominance of some traits in a population and the suppression of other traits. Students will pay attention to precise details in explanations from specific textual evidence and will cite this evidence to support their analysis and reflection on research that explains how genetic variation of traits in a population increases some individuals' probability of surviving and reproducing in a specific environment. Students will compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading these texts and write informative/explanatory texts on how natural selection leads to the predominance of some traits and the suppression of others in a population. Students will engage effectively in a range of collaborative discussions where they will present their claims and findings. These discussions may be one-on-one between students, in small groups, or teacher-led large group discussions. In these discussions, students will build on others' ideas while expressing their own clearly. Claims must emphasize salient points in a focused, coherent manner, supported with relevant evidence, sound valid reasoning, and well-chosen details. Students must use appropriate eye contact, adequate volume, and clear pronunciation. There are multiple activities available that show students how one trait can provide a survival advantage over another in a specific environment. As part of these activities, students can analyze data and determine ratio relationships to provide evidence of cause-and-effect relationships. These ratios can be used to explain why some inherited traits result in individuals that have a survival advantage in a specific environment over time or why other traits in a population are suppressed. When an environment changes as a result of human influence and/or natural processes on Earth, traits that were present in populations of organisms and that led to a survival advantage in that environment before the change may no longer offer an advantage. Changes in environmental conditions can

be the driving cause of the suppression of traits in populations.

Students will examine a variety of environmental factors that may influence the natural selection that is taking place in populations. Students will need to use simple probability statements and proportional reasoning to explain why each factor may or may not be responsible for the changes being observed. Students will compare and contrast the information gained from experiments, simulations, video, or multimedia sources with information gained from reading science and technical texts to support their explanations. After students have constructed their explanations, they will participate in collaborative discussions in small groups; in larger, teacher-led groups, or in pair.

After students have developed a strong understanding of natural selection, they will need to begin gathering evidence from multiple sources, including print and digital, to support analysis of information about technologies that have changed how humans can influence the inheritance of desired traits in organisms (artificial selection). Students need to examine current technologies as well as the technologies that have led to these scientific discoveries. Students will cite the information they gathered and quote or paraphrase relevant data and conclusions from their resources to describe the impact that current technologies have on society. Some of the influences of humans on genetic outcomes in artificial selection that students can examine include genetic modifications, animal husbandry, and gene therapy.

Students can be provided with multiple sources to determine the credibility, accuracy, and possible bias of the resources. In order to determine the best sources, students can investigate and describe how information in these resources is supported or not supported by evidence. Once students have determined appropriate sources, they can begin to synthesize information about the technologies that have changed how humans can influence the inheritance of desired traits in organisms (artificial selection). Students can quote or paraphrase the data and conclusions and provide basic bibliographic information. They can do this in a variety of ways (e.g., in writing, verbal discussion, debate, Socratic seminar, etc.).

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Connecting with English Language Arts/Literacy and Mathematics
English Language Arts/Literacy Cite specific textual evidence to support analysis of scientific and technical texts about how genetic variations in a population increase some individuals' probability of surviving and reproducing in a specific environment. Attention must be paid to precise details of explanations or descriptions. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with information gained from reading a text on how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. Write informative/explanatory texts examining how natural selection leads to the predominance of some traits in a population and the suppression of others. Convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. Draw evidence from informational texts to support the analysis, reflection, and research used to construct an explanation of how genetic variation of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. Engage effectively in a range of collaborative discussions with diverse partners to discuss how natural selection leads to the predominance of certain traits in a population and the suppression of others. Discussions may be one-on-one, in groups, or teacher-led; in these discussions, students should build on others' ideas while expressing their own clearly. Present claims and findings about how natural selection leads to the predominance of certain traits in a population and the suppression of others. Claims must emphasize salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details. Students must use appropriate eye contact, adequate volume, and clear pronunciation. Cite specific textual evidence to support analysis of information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms (artificial selection). Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others about technologies that have changed the way humans influence the inheritance of desired traits. Avoid plagiarism and provide basic bibliographic information for sources. *Mathematics*

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Understand the concept of a ratio and use ratio language to describe a ratio relationship between specific genetic variations in a population and the probability of some individuals in that populations surviving and reproducing in a specific environment. Summarize numerical data sets about a ratio relationship between genetic variations in a population and the probability of some individuals in that population surviving and reproducing in a specific environment. Recognize and represent proportional relationships in trends in changes to populations over time. Use mathematical models to support explanations of trends in changes to populations over time. Understand the concept of a ratio and use ratio language to describe a ratio relationship between natural selection and decreases of specific traits in populations over time. Summarize numerical data sets to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

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)

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Research on Student Learning
Students, even after some years of biology instruction, have difficulties understanding the notion of natural selection. A major hindrance to understanding natural selection appears to be students' inability to integrate two distinct processes in evolution, the occurrence of new traits in a population and their effect on long-term survival. Many students believe that environmental conditions are responsible for changes in traits, or that organisms develop new traits because they need them to survive, or that they over-use or under-use certain bodily organs or abilities. By contrast, students have little understanding that chance alone produces new heritable characteristics by forming new combinations of existing genes or by mutations of genes. Some students believe that a mutation modifies an individual's own form during its life rather than only its germ cells and offspring (see almost any science fiction movie). Students also have difficulties understanding that changing a population results from the survival of a few individuals that preferentially reproduce, not from the gradual change of all individuals in the population. Explanations about "insects or germs becoming more resistant" rather than "more insects or germs becoming resistant" may reinforce these misunderstandings. Specially designed instruction can improve students' understanding of natural selection. Students may have difficulties with the various uses of the word "adaptation". In everyday usage, individuals adapt deliberately. But in the theory of natural selection, populations change or "adapt" over generations, inadvertently Students of all ages often believe that adaptations result from some overall purpose or design, or they describe adaptation as a conscious process to fulfill some need or want. Elementary- and middle-school students also tend to confuse non-inherited adaptations acquired during an individual's lifetime with adaptive features that are inherited in a population (NSDL, 2015)

Prior Learning
By the end of Grade 5, students understand that: • Different organisms vary in how they look and function because they have different inherited information. • The environment also affects the traits that an organism develops. • Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing. • For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.

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Future Learning
Life Science and Environmental Science • Ecosystems have carrying capacities, which are limits on the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources, 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. • 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, the ecosystem may return to its original status, more or less (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 (i.e, 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. • In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. • Environmental factors also affect the expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed in a population depends on both genetic and environmental factors. • Natural selection occurs only if there is both (1) variation in the genetic information among 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. 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.

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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.

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Sample of Open Education Resources
99.99% Antibacterial Products and Natural Selection: This activity is a hands-on simulation using Skittles and mini-marshmallows to show how natural selection can act as a mechanism to increase the presence of antibacterial resistance in a population. An Origin of Species: Pollenpeepers: This web simulation allows students to explore adaptive radiation of a fictitious group of birds called Pollenpeepers over a period of 5 million years. Making Sense of Natural Selection: This article from The Science Teacher magazine describes a unit of study on natural selection. Students begin by trying to explain the phenomenon of the exponential increase in a population of fish. Bug Hunt "Bug Hunt" uses NetLogo software and simulates an insect population that is preyed on by birds. There are six speeds of bugs from slow to fast and the bird tries to catch as many insects as possible in a certain amount of time. Students are able to see the results graphed as the average insect speed over time, the current bug population and the number of insects caught. Color Variation over Time in Rock Pocket Mouse Populations: This activity provides an introduction to natural selection and the role of genetic variation by asking students to analyze illustrations of rock pocket mouse populations (dark/light fur) on different color substrates in the Sonoran Desert (light/dark) over time. Based on this evidence, and what they learn about variation and natural selection in the accompanying short film, students use this evidence to explain the change in the rock pocket mouse populations on the lava flow (dark substrate) over time. Catch Up on Tomato Technology: This lesson is a tool to demonstrate how various technological advances have changed the tomato and the tomato industry over the years. The technology includes both selective breeding and genetic engineering.

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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	**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	**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***

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)	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)	***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)

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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**

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Common Vocabulary	
Diversity Life form Sedimentary Chronological order Fossil record History of life	Natural law Anatomical Ancestry Radioactive dating

Unit 3: Stability and Change on Earth

Instructional Days: 30

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)**

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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)**

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(MS-ESS3-1	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-ESS3-2	Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects
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.
MS-ESS3-5	Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century
ESS3.A	Humans depend on Earth's land, ocean, atmosphere and biosphere for many different resources
ESS3.B	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
ESS3.C	Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species
ESS3.D	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

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Quick Links		

Enduring Understandings
• Some natural disasters are predictable while others are not • Natural disasters are driven by interior processes, surface processes, and/or severe weather events • Human activity impacts ecosystems • The relationship between human population and the impact on natural resources
Essential Questions
• What are resources? • Why do natural disasters occur? • How do humans impact the environment? • What affects climate change?

Unit 3: Stability and Change on Earth

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<table>
<tr><th colspan="2">Unit Sequence</th></tr>
<tr><td colspan="2">Part A: Why aren’t minerals and groundwater distributed evenly across the world?</td></tr>
<tr><th>Concepts</th><th>Formative Assessments</th></tr>
<tr><td>

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.

</td><td>
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.

</td></tr>
</table>

Unit 3: Stability and Change on Earth

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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 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.	*Students who understand the concepts can:* • Analyze and interpret data on natural hazards to determine similarities and differences and to distinguish between correlation and causation.

Unit 3: Stability and Change on Earth

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<table>
<tr><th colspan="2">Unit Sequence</th></tr>
<tr><td colspan="2">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?)</td></tr>
<tr><th>Concepts</th><th>Formative Assessments</th></tr>
<tr><td>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.
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.</td><td>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.</td></tr>
</table>

Unit 3: Stability and Change on Earth

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<table>
<tr><th colspan="2">Unit Sequence</th></tr>
<tr><td colspan="2">Part D: How can basic chemistry be used to explain the mechanisms that control the global temperature the atmosphere?</td></tr>
<tr><th>Concepts</th><th>Formative Assessments</th></tr>
<tr><td>

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 activities.

</td><td>
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.

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Unit 3: Stability and Change on Earth

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What It Looks Like in the Classroom
Students will begin by building on their prior knowledge that human activities affect the Earth. Students will describe how human activities have positive as well as negative impacts on land, ocean, atmosphere, and biosphere resources. In this unit of study, students will build upon this knowledge by examining the causes of the uneven distribution of resources on Earth. Students can then write an informative text to explain the causes of uneven distributions of Earth's minerals, energy, and groundwater resources. These causes can include past and current geosciences processes as well as human removal of resources. The written text needs to include specific evidence to support the student's explanation. Students will use variables to represent numbers and write expressions. They will convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. Students will perform investigations to gather data showing how natural processes can lead to the uneven distributions of Earth's mineral, energy, and groundwater resources. The resources considered should include but not be limited to petroleum, metal ores, and soil. An example of an investigation could include using models of different layers of sediment that will show the uneven distribution of groundwater as it permeates through different types of soil and rock. A saturated mineral solution (i.e. salt) can be poured over the sedimentary layers and then evaporated to leave behind a deposit. Students could then take core samples using straws to gather data from the model. Emphasis is on how these resources, including land, ocean, atmosphere, biosphere, mineral, and fresh water, are limited and typically are nonrenewable, and how their distributions are significantly changing as a result of removal by humans. Students will use variables to represent quantities and construct simple equations and inequalities to solve problems by reasoning about the quantities. Students may use maps showing the current global distribution of different resources along with maps showing past global distribution of the same resources to gather data. Students could use these data to create mathematical expressions that could show the impact of current human consumption on possible future resource distribution (renewable and nonrenewable energy resources). In addition, students could use maps of different geosciences processes alongside other data to explain the uneven distributions of Earth's resources. Students will continue to learn about Earth's systems as they consider how natural hazards can be the result of interior processes, surface processes, or severe weather events. They will learn that 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. Students will also look at how technology can be used to predict natural hazards to reduce their impacts. Last, students will examine evidence of natural processes and human activities that have caused global climate change.

Students can analyze maps, charts, and images of natural hazards to look for patterns in past occurrences of catastrophic events. Data on natural hazards can include the locations, magnitudes, and frequencies of the natural hazards. Students can use these data to make reliable predictions of future catastrophic events.

Students can also look at past occurrences of catastrophic events to determine how those events have influenced the development of technologies scientists use to predict future events. It might be useful to include local catastrophic events, since the technology used to predict and diminish effects of future events varies from region to region over time. Some of the data students might analyze could include locations, magnitudes, and frequencies of the natural hazards.

Students will continue their study of Earth's systems and processes by investigating the impact of sudden events or gradual changes that accumulate over time and affect the stability of Earth's surface temperature.

Students will cite specific textual evidence to support an argument about the role of human activity and natural processes in the gradual increase in global temperatures over the past century.

Students can ask questions to clarify how human activities, such as the release of greenhouse gases from the burning of fossil fuels, play major roles in the rise in global temperatures. Students can also ask questions about how natural events, such as volcanic activity, also contribute to the rise in global temperature. Students can look at a variety of sources for evidence, such as tables, graphs, and maps of global and regional temperatures; atmospheric levels of gases, such as carbon dioxide and methane; and rates of human activities, to support an argument that global temperatures have risen over the past century. Students can use these data to write mathematical expressions that show relationships between these variables.

Students will examine a variety of changes that humans have made to Earth's natural systems and determine whether these changes have positive impacts, negative impacts, or some combination of positive and negative impacts. As part of this study, students will collect evidence to support arguments they develop about the impact of the modifications to Earth's systems. Students will consider how a variety of human actions can impact an ecosystem. Among the human actions considered will be human population growth and the consumption of resources from the ecosystem. Students will prepare a report on the system and describe how the system is impacted. Evidence must be recorded to support their arguments and must be presented in both an oral and a written format.

Students can cite specific textual evidence to develop an argument about the need to reduce the level of climate change due to human activity. The argument can include the need for reduction in human vulnerability to whatever climate change occurs as a result of natural events.

This unit of study will be will be leveraged in the Unit 4 engineering and design process.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

Cite specific textual evidence to support analysis of how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geosciences processes.

Write informative/explanatory texts examining how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geosciences processes. Convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

Draw evidence from informational texts to support analysis, reflection, and research on how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geosciences processes.

Cite specific textual evidence in data used to support the analysis of natural hazards and to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Integrate quantitative or technical information about natural hazards and forecasting future catastrophic events that is expressed visually (e.g., in a flowchart, diagram, model, graph, or table). Use the integrated text and visual displays to analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Cite specific textual evidence to support an argument about the role of human activity and natural processes in the gradual increase in global temperatures over the past century.

Mathematics

Use variables to represent numbers and write expressions for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geosciences processes. Convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

Unit 3: Stability and Change on Earth

Instructional Days: 30

Use variables to represent quantities for how the distribution of Earth's mineral, energy, and groundwater resources are significantly changing as a result of removal by humans. Construct simple equations and inequalities to solve problems by reasoning about the quantities. Analyze and interpret data on natural hazards by reasoning abstractly (manipulating symbols abstractly) and quantitatively (while attending to the meaning of those symbols) to forecast future catastrophic events and inform the development of technologies to mitigate their effects. Use variables to represent numbers and write expressions for the locations, magnitudes, and frequencies of natural hazards and how these data can be used to forecast future catastrophic events and inform the development of technologies to mitigate their effects. The variable can represent an unknown number or, depending on the purpose at hand, any number in a specified set. Use variables to represent quantities for the location, magnitudes, and frequencies of natural hazards and how these data can be used to forecast future catastrophic events and inform the development of technologies to mitigate their effects. Construct simple equations and inequalities to solve problems by reasoning about the quantities. Students will clarify evidence of the factors that have caused the rise in global temperatures over the past century, reasoning abstractly (manipulating symbols abstractly) and quantitatively (while attending to the meaning of those symbols). Use variables to represent numbers and write expressions for data found in 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. The variable can represent an unknown number or, depending on the purpose at hand, any number in a specified set. Use variables to represent quantities found in 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. Construct simple equations and inequalities to solve problems by reasoning about the quantities.

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
N/A

Unit 3: Stability and Change on Earth

Instructional Days: 30

Prior Learning
By the end of Grade 5, students understand that: • The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. • Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. • A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). • Humans cannot eliminate the hazards but can take steps to reduce their impacts. • Populations live in a variety of habitats, and change in those habitats affects the organisms living there. • Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments.

Future Learning
This unit of study will be will be leveraged in the Unit 4 engineering and design process. • 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).

- 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 used 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.
- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- Evidence from deep probes, seismic waves, reconstructions of historical changes in Earth's surface and 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 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.

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- 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.
- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These physical and chemical properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks.
- 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 foundation for Earth's global climate systems is the electromagnetic radiation from the sun, along with 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.
- 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.
- 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.
- 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.
- The sustainability of human societies and the biodiversity that supports them require 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.

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.

Sample of Open Education Resources
USGS Educational Resources for Secondary Grades (7–12): This web site contains selected USGS educational resources that may be useful to educators in secondary school grades. Many of these resources can be used directly in the classroom or will be useful in classroom lessons or demonstration activities preparation, or as resources for teacher education and curriculum development.   NOAA Education Resources: This website contains access to curriculum resources, professional development opportunities, student opportunities, and outreach events.

Unit 3: Stability and Change on Earth

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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	**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**

	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 human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)	**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) - ***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)

Unit 3: Stability and Change on Earth

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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**

Common Vocabulary	
Conservation	Mineral
Nonrenewable energy	Physical replica
Renewable energy	Economic
Agricultural	Energy source
Biosphere	Geologic trap
Development	Impact
Groundwater	Issue
Material world	Organic

Unit 3: Stability and Change on Earth

Instructional Days: 30

Unit 4: Human Impact

Instructional Days: 25

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)

Unit 4: Human Impact

Instructional Days: 25

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)

MS-ESS3-3	Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
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
MS-ETS1-2	Evaluate competing design solutions using a systematic process to 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
ETS1.B	There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem

Unit 4: Human Impact

Instructional Days: 25

Quick Links		

Enduring Understandings
• Some natural disasters are predictable while others are not • Natural disasters are driven by interior processes, surface processes, and/or severe weather events • Human activity impacts ecosystems • The relationship between human population and the impact on natural resources
Essential Questions
• What are resources? • Why do natural disasters occur? • How do humans impact the environment? • What affects climate change?

Unit 4: Human Impact

Instructional Days: 25

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.

Unit 4: Human Impact

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What It Looks Like in the Classroom
Throughout this unit of study, students will be engaged in the engineering design process. Students can start by identifying a human impact on the environment that has resulted from human consumption of natural resources. Using what they have identified, students will begin to define the criteria and constraints of the design problem whose solution will help to monitor and minimize the human impact on the environment. Using informational texts to support this process is important. Students will draw evidence from these texts in order to support their analysis, reflection, and research. When students consider criteria, they should conduct short research projects to examine factors such as societal and individual needs, cost effectiveness, available materials and natural resources, current scientific knowledge, and current advancements in science and technology. They should also consider limitations due to natural factors such as regional climate and geology. While conducting their research, students will need to gather their information from multiple print and digital sources and assess the credibility of each source. When students quote or paraphrase the data and conclusions found in these resources, they will need to avoid plagiarism and provide basic bibliographic information for each source. After comparing the information gained from their research, experiments, simulations, video, or other multimedia sources, they will be able to determine precise design criteria and constraints that lead to a successful solution. Students will need to jointly develop and agree upon the design criteria that will be used to evaluate competing existing design solutions (i.e., varying dam designs, irrigation systems, varying methods of reducing pollution, varying methods of urban development). Students can use a rubric, checklist, or decision tree to assist them in evaluating the design solution selected. Students can be provided with data from tests performed on these existing design solutions. They will analyze and interpret these data to determine similarities and differences in findings. This is where they are deciding where different parts of the pre-existing solutions can be combined. For example, the building materials of a particular dam may be superior while the shape of another design may be more suitable. Students should consider the ratio relationship between the impacts that humans have on the environment and the impact that the design solution has on minimizing these impacts. Students will need to consider both qualitative and quantitative data when drawing conclusions about the various design solutions. It is important that students handle mathematical data appropriately. They should use variables to represent quantities and construct simple equations and inequalities to solve problems. While analyzing numerical data, students will need to solve mathematical problems that show both positive and negative values and apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental

computations and estimation strategies. Support from mathematics teachers will help students with the mathematics required for this type of analysis.

Once students have evaluated competing solutions and analyzed and interpreted data showing the similarities and differences of these solutions, they may then begin designing their own solutions. It is important that students consider the benefits and risks of each existing design solution. The impact on the environment and human society must be considered in the design. The final goal for students is to identify the parts of each design solution that best fit their criteria and constraints and combine these parts into a design solution that is better than any of its predecessors.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Conduct short research projects to determine a method for monitoring and minimizing a human impact on the environment, drawing on several sources and generating additional, related, focused questions that allow multiple avenues of exploration.
- Gather relevant information from multiple print and digital sources about a method for monitoring and minimizing a human impact on the environment, assess the credibility of each source, and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.
- Draw evidence from informational texts about minimizing a human impact on the environment to support analysis, reflection, and research.
- Cite specific textual evidence about a method for monitoring and minimizing a human impact on the environment to support analysis of science and technical texts.
- Compare and contrast the information gained from experiments, simulations, videos, or multimedia sources with that gained from reading a text on a method for monitoring and minimizing a human impact on the environment.
- Integrate quantitative or technical information about a method for monitoring and minimizing a human impact on the environment expressed in words with a version of that information expressed visually.

Unit 4: Human Impact

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Mathematics

- Use abstract and quantitative reasoning to analyze and interpret data in order to determine similarities and differences in findings of how well designed methods meet the criteria and constraints of solutions that could reduce a human impact on the environment.
- Understand the concept of a ratio and use ratio language to describe a ratio relationship between *human impacts on environments and the impact of methods to minimize these impacts.*
- Use variables to represent quantities when analyzing and interpreting data to determine how well designed methods meet the criteria and constraints of solutions that could reduce a human impact on the environment and construct simple equations and inequalities to solve problems by reasoning about the quantities.
- While analyzing data to determine how well designed methods meet the criteria and constraints of solutions that could reduce a human impact on the environment, solve multistep 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; covert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

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
N/A

Unit 4: Human Impact

Instructional Days: 25

Prior Learning
By the end of Grade 5, students understand that: When the environment changes in ways that affect a place's physical characteristics, temperature, or resource availability, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. Students also know that populations live in a variety of habitats, and change in those habitats affects the organisms living there. Human activities in agriculture, industry, and everyday life have major effects on land, vegetation, streams, oceans, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. A simple design problem can be solved through the development of an object, tool, process, or system, and the solution can include several criteria for success and constraints on materials, time, or cost. Students know that they can test two different models of the same proposed object, tool, or process to determine which better meets criteria for success. Students also analyzed data to refine a problem statement or the design of a proposed object, tool, or process and used data to evaluate and refine design solutions. They applied scientific ideas to solve design problems and generate and compare multiple solutions to a problem based on how well they met the criteria and constraints of the design solution. Students have made claims about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.

Future Learning
• A complex set of interactions within an ecosystem can keep numbers and types of organisms in the ecosystem relatively constant over long periods of time under stable conditions. • If a modest biological or physical disturbance to an ecosystem occurs, the ecosystem may return, more or less, to its 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 can challenge the functioning of ecosystems in terms of resources and habitat availability. • 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.

Unit 4: Human Impact

Instructional Days: 25

- 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. The differential survival and reproduction of organisms within a population that have an advantageous heritable trait lead 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 an altered environment.
- If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.
- Humans depend on the living world for 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.
- 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.
- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks.
- The foundation of Earth's global climate system 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.
- 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.
- 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 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.

Unit 4: Human Impact

Instructional Days: 25

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.

Unit 4: Human Impact

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Sample of Open Education Resources
USGS Educational Resources for Secondary Grades (7–12): This web site contains selected USGS educational resources that may be useful to educators in secondary school grades. Many of these resources can be used directly in the classroom or will be useful in classroom lessons or demonstration activities preparation, or as resources for teacher education and curriculum development. NOAA Education Resources: This website contains access to curriculum resources, professional development opportunities, student opportunities, and outreach events.

Unit 4: Human Impact

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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 world	**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	**Cause and Effect** • Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. (MS-ESS3-3) -

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)	positive) for different living things. (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	***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

	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)	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)	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-

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**	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**

Common Vocabulary	
Natural process	Geologic
Resistant	Impact
Natural resource	Magnitude
Development	Satellite
Reservoir	Frequency
Catastrophic	Interdependence
Debris	Mass wasting
Economic	

Unit 5: Relationships Among Forms of Energy

Instructional Days: 20

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)**

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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
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
MS-PS3-5	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
PS3.A	A system of objects may also contain stored energy, depending on their relative positions
PS3.B	Energy is spontaneously transferred out of hotter regions or objects and into colder ones
PS3.C	When two objects interact, each on exerts a force on the other that can cause energy to be transferred to or from the object

Unit 5: Relationships Among Forms of Energy

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Quick Links		

Enduring Understandings

- 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

Essential Questions

- What is energy?
- How is energy conserved and transferred?
- What is the relationship between energy and forces?

Unit 5: Relationships Among Forms of Energy

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

Unit 5: Relationships Among Forms of Energy

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<table>
<tr><th colspan="2">Unit Sequence</th></tr>
<tr><td colspan="2">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?</td></tr>
<tr><th>Concepts</th><th>Formative Assessments</th></tr>
<tr><td>• 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.</td><td>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.</td></tr>
</table>

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<table>
<tr><th colspan="2">Unit Sequence</th></tr>
<tr><td colspan="2">Part C: Who can design the best roller coaster?</td></tr>
<tr><th>Concepts</th><th>Formative Assessments</th></tr>
<tr><td>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).</td><td>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.</td></tr>
</table>

Unit 5: Relationships Among Forms of Energy

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What It Looks Like in the Classroom
Prior to middle school, students know that energy is present whenever there are moving objects, sound, light, or heat and that when objects collide, energy can be transferred from one object to another, thereby changing the objects' motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. Students also know that when objects collide, the contact forces transfer energy so as to change the objects' motions. Students will need to construct graphical displays of data that describe the relationships between kinetic energy and mass of an object and speed of an object. These displays can be based on information from examples such as riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a whiffle ball versus a tennis ball. Through using one of these examples, students can record either mass or speed data to identify linear and nonlinear relationships. When constructing and interpreting graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object, students will 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 number. A simple demonstration of how increased speed or mass contributes to increased kinetic energy could include two objects of different masses (e.g., balls) rolling into a targets (e.g., plastic bowling pins, wooden blocks, etc.). From these examples, students will also be able to describe differences between kinetic energy and mass separately from kinetic energy and speed. Students will understand that an increase in speed will have a different effect on kinetic energy than an increase in mass. They will recognize and represent proportional relationships between kinetic energy and mass separately from kinetic energy and speed. Students will include a narrative that explains the information found in their graphical displays. Students investigate the potential energy stored in a variety of systems. It will be necessary for students to have opportunities to rearrange objects in the systems in order to determine the impact on the amount of potential energy stored in the system. Systems to be investigated could be balloons with static electrical charge being brought closer to a classmate's hair, carts at varying positions on a hill, cars at different positions on hot wheels tracks, objects at varying heights on shelves (drop a book of the same mass from different heights onto a cup) to demonstrate changes to potential energy in a system. Students will develop models to describe how changing distance changes the amount of potential energy stored in the system. The models students use to describe any of these examples will be multimedia presentations that could include diagrams, pictures, and/or written descriptions of the system examined. These models will help students represent interactions within systems, such as inputs, processes, and outputs, and energy flows within the system.

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Students will now have an opportunity to use an understanding of kinetic and potential energy within a system to construct a claim about the relationship between the transfer of energy to or from an object and changes in kinetic energy. Using data from the graphical displays of data and models that students developed earlier in this unit of study, as well as textual evidence, students will construct, use, and present oral and written arguments to support claims that when kinetic energy changes, energy is transferred to or from the object.

Students can provide evidence of this energy transfer by looking at the distance an object travels when energy is transferred, how temperature changes when energy is transferred, or how a compass responds to a magnetic field at different distances. Students will 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, but they are not required to include calculations of energy. However, students should interpret the equation $y = mx + b$ as defining a linear function whose graph is a straight line and be able to give examples of functions that are not linear when describing the change in the kinetic energy of an object and the energy transferred to or from the object.

Connecting with English Language Arts/Literacy and Mathematics
English Language Arts/Literacy Cite specific textual evidence to support analysis of science and technical texts that describe the relationships of kinetic energy to the mass of an object and to the speed of an object, attending to the precise details of explanations or descriptions. Integrate quantitative or technical information that describes the relationship of kinetic energy to the mass of an object and to the speed of object that is expressed in words with a version of that information expressed visually in a flowchart, diagram, model, graph, or table. Integrate multimedia and visual displays into presentations that describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system to clarify information, strengthen claims and evidence, and add interest. Cite specific textual evidence to support analysis of science and technical texts to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object, attending to the precise details of explanations or descriptions. Write arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the

object.

Mathematics

Reason abstractly and quantitatively by interpreting numerical, graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

Describe a ratio relationship between kinetic energy and mass separately from kinetic energy and speed.

Understand the concept of a unit rate a/b associated with a ratio a:b with b≠, and use rate language in the context of a ratio relationship between kinetic energy and mass separately from kinetic energy and speed.

Recognize and represent proportional relationships between kinetic energy and mass separately from kinetic energy and speed.

Know and apply the properties of integer exponents to generate equivalent numerical expressions when describing the relationships between kinetic energy and mass separately from kinetic energy and speed.

When constructing and interpreting graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object, 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 number. Evaluate square roots of small perfect squares and cube roots of small perfect cubes. Know that $\sqrt{2}$ is irrational.

When constructing and interpreting graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object, 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.

Reason abstractly and quantitatively when analyzing data to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Understand the concept of ratio and use ratio language to describe the ratio relationships between the change in the kinetic energy of an object and the energy transferred to or from the object.

Recognize and represent proportional relationships between the change in the kinetic energy of an object and the energy transferred to or from the object.

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 when describing the change in the kinetic energy of an object and the energy transferred to or from the object.

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 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. 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 middle- school students who hold on to the everyday use of the term energy. 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, middle 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) (NSDL, 2015)

Prior Learning

By the end of Grade 5, students understand that:

- Energy is present whenever there are moving objects, sound, light, or heat.
- When objects collide, energy can be transferred from one object to another, thereby changing the objects' motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.
- Light also transfers energy from place to place.
- Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light.
- Transforming the energy of motion into electrical energy may have produced currents.
- When objects collide, the contact forces the transfer of energy so as to change the objects' motions.

Unit 5: Relationships Among Forms of Energy

Instructional Days: 20

Future Learning
• 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 of 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). • 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.

Unit 5: Relationships Among Forms of Energy

Instructional Days: 20

Connections to Other Units
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: Interaction 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 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** • 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.

Unit 5: Relationships Among Forms of Energy

Instructional Days: 20

Sample of Open Education Resources
Soccer - Kick It**:** In this video, watch how two young soccer players investigate the relationship between the size of a player's leg and how far the ball can be kicked. It's All Downhill: Forces and Sports Lesson Plan**:** This lesson plan allows the learner to do free research to find information on a sport and the physics in that particular sport. This lesson references a streaming video from Discovery School. It is not entirely necessary to complete the lesson. Energy Skate Park: Basics: With this lesson, students learn about conservation of energy with a skateboarding simulation. Students build tracks, ramps, and jumps for the skater and view the kinetic energy, potential energy and friction as he moves. There are teacher-suggested lessons using the simulation. Energy: Different Kinds of Energy: Students use simulations to learn about potential and kinetic energy, how it is classified and how to calculate it.

Unit 5: Relationships Among Forms of Energy

Instructional Days: 20

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)**

Unit 5: Relationships Among Forms of Energy

Instructional Days: 20

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) **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	**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 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)	**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, 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)

logical and conceptual connections between evidence and explanations (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-PS3-2)* **SL.8.5**	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 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

Instructional Days: 20

Common Vocabulary	
Orientation Albert Einstein Bernoulli's principle Buoyancy Elasticity Electric field Inertial frame of reference Magnetic field	Mass to energy conversion Special theory of relativity Speed of light Torque Conversion Particle Store Transfer

Unit 1: Structures and Properties of Matter

Instructional Days: 30

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 1: Structures and Properties of Matter

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MS-PS3-3	Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer
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
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
MS-ETS1-2	Evaluate competing design solutions using a systematic process to 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.
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
ETS1.A	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
ETS1.B	There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem

Unit 1: Structures and Properties of Matter

Instructional Days: 30

Quick Links		

Enduring Understandings
• 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
Essential Questions
• What is energy? • How is energy conserved and transferred? • What is the relationship between energy and forces?

Unit 1: Structures and Properties of Matter

Instructional Days: 30

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 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.	*Students who understand the concepts can:* • 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 1: Structures and Properties of Matter

Instructional Days: 30

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 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.	*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 well they meet criteria and constraints.

Unit 1: Structures and Properties of Matter

Instructional Days: 30

What It Looks Like in the Classroom
In Unit 5, students learned about the interactions between kinetic and potential energy. In this unit, they will be introduced to the idea of thermal energy and will explore how it relates to the interactions from Unit 5. Prior to planning an investigation, students will need to understand that temperature is actually a measure of the average kinetic energy of the particles in a sample of matter. Students will begin this unit by individually and collaboratively planning an investigation to determine energy transfer 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. Students could start with an individual, small-group, or whole-class brainstorm to determine what might happen if they changed the temperature in a sample of matter. This brainstorm could take the form of a sketch, graphic organizer, or written response, and it could include everyday activities like taking a can of soda out of the refrigerator and setting it on a table or putting an ice cube into a warm beverage. After brainstorming, students may need some guidance to determine what variables they would like to test in their experiment. Students could examine how the mass of ice cubes added to the beverage affects the temperature change. They could also investigate how the mass of the can of soda affects the temperature change as it sits on the table after being removed from the refrigerator. Examples of experiments could include a comparison of final temperatures after different masses of ice have melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials as they cool or heat in the environment, or the same material with different masses when a specific amount of thermal energy is added. Another example could include placing heated steel washers into water to investigate temperature changes. Each of these examples helps to show the proportional relationship between different masses of the same substance and the change in average kinetic energy when thermal energy is added to or removed from the system. In planning, students will identify independent and dependent variables and controls, decide what tools and materials are needed, how measurements will be recorded, and how many data are needed to support their claim. Once experiments have been planned and performed, students will move into the engineering process to solve a problem using this content. In Unit 4, students used the design and engineering process to maximize a solution to a problem. In this unit of study, students will combine the concepts of thermal energy and engineering processes to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. Examples of devices could include an insulated box, a solar cooker, or a Styrofoam cup. Calculation of the total amount of thermal energy is not to be assessed at this time.

Based on their brainstorm and investigations, students will identify a device to control the transfer of thermal energy into or out of the system they studied. Once students have identified the type of device they will construct, they can begin to define the criteria and constraints of the design problem that will help to minimize or maximize the transfer of thermal energy. Using informational texts to support this process is important. Students will draw evidence from these texts in order to support their analysis, reflection, and research.

When students consider constraints, they should conduct short research projects to examine factors such as societal and individual needs, cost effectiveness, available materials and natural resources, current scientific knowledge, and current advancements in science and technology. They should also consider limitations (design constraints) due to the properties of the materials of their design (i.e., Styrofoam vs. glass). While conducting their research, students will need to gather their information from multiple print and digital sources and assess the credibility of each source. When they quote or paraphrase the data and conclusions found in their resources, they will need to avoid plagiarism and provide basic bibliographic information for each source. After comparing the information gained from their research, experiments, simulations, video, or other multimedia sources, they will be able to determine precise design criteria and constraints that lead to a successful solution.

Unit 1: Structures and Properties of Matter

Instructional Days: 30

Connecting with English Language Arts/Literacy and Mathematics
English Language Arts/Literacy • Follow precisely a multistep procedure for an investigation that has been planned individually and collaboratively 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. • Conduct short research projects 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, drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. • Follow precisely a multistep process for the design, construction, and testing of a device that either minimizes or maximizes thermal energy transfer. • Conduct short research projects to apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer, drawing on several sources and generating additional related, focused questions that allow for multiple avenue of exploration. • Gather relevant information to inform the design, construction, and testing of a device that either minimizes or maximizes thermal energy transfer using multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources. • Draw evidence from informational texts to support analysis, reflection, and research that informs the design, construction, and testing of a device that either minimizes or maximizes thermal energy transfer. • Cite specific textual evidence to support analysis of science and technical texts that provide information about the application of scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. • Compare and contrast the information gained from experiments, simulations, or multimedia sources with that gained from reading text about devices that either minimize or maximize energy transfer. *Mathematics* • Reason abstractly and quantitatively while collecting and analyzing numerical and symbolic data as part of an investigation

that has been planned individually and collaboratively.

- Summarize numerical data sets in relation to the amount of energy transferred, the type of matter, the mass, and the change in the average kinetic energy of particles in the sample as measured by the temperature of the sample.
- Reason abstractly and quantitatively while collecting and analyzing numerical and symbolic data as part of a systematic process for evaluating solutions with respect to how well they meet criteria and constraints of a problem involving the design of a device that either minimizes or maximizes thermal energy transfer.

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 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. 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 middle- school students who hold on to the everyday use of the term energy. 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, middle 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) (NSDL, 2015)

Prior Learning
By the end of Grade 5, students understand that: • Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. • Light transfers energy from place to place. • Energy can be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. • Transforming the energy of motion into electrical energy may have produced the currents to begin with. • When objects collide, the contact forces transfer energy so as to change the objects' motions.

Unit 1: Structures and Properties of Matter

Instructional Days: 30

Future Learning
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. • 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).
- 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.
- 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.
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different 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 approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

Unit 1: Structures and Properties of Matter

Instructional Days: 30

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.

Unit 1: Structures and Properties of Matter

Instructional Days: 30

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.

Sample of Open Education Resources
Energy Forms and Changes: Explore how heating and cooling iron, brick, and water adds or removes energy. See how energy is transferred between objects. Build your own system, with energy sources, changers, and users. Track and visualize how energy flows and changes through your system. States of Matter: Watch different types of molecules form a solid, liquid, or gas. Add or remove heat and watch the phase change. Change the temperature or volume of a container and see a pressure-temperature diagram respond in real time. Relate the interaction potential to the forces between molecules.

Unit 1: Structures and Properties of Matter

Instructional Days: 30

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)

Unit 1: Structures and Properties of Matter

Instructional Days: 30

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 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	**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) **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	**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) **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

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)	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** • Although one design may not perform the best across all tests, identifying the characteristics of the design that	scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

	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)	

Unit 1: Structures and Properties of Matter

Instructional Days: 30

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** 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**	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**

Unit 1: Structures and Properties of Matter

Instructional Days: 30

Common Vocabulary	
Orientation	Mass to energy conversion
Albert Einstein	Special theory of relativity
Bernoulli's principle	Speed of light
Buoyancy	Torque
Elasticity	Conversion
Electric field	Particle
Inertial frame of reference	Store
Magnetic field	Transfer

Unit 7: The Electromagnetic Spectrum

Instructional Days: 20

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 7: The Electromagnetic Spectrum

Instructional Days: 20

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.
MS-PS4-2	Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
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
PS4.A	A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude
PS4.B	A wave model of light is useful for explaining brightness, color, and the frequency dependent bending of light at a surface between media
PS4.C	Digitized signals are a more reliable way to encode and transmit information

Unit 7: The Electromagnetic Spectrum

Instructional Days: 20

Quick Links		

Enduring Understandings
• 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
Essential Questions
• What is energy? • How is energy conserved and transferred? • What is the relationship between energy and forces?

Unit 7: The Electromagnetic Spectrum

Instructional Days: 20

<table>
<tr><th colspan="2">Unit Sequence</th></tr>
<tr><td colspan="2">Part A: Why do surfers love physicists?</td></tr>
<tr><th>Concepts</th><th>Formative Assessments</th></tr>
<tr><td>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.</td><td>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.</td></tr>
</table>

Unit 7: The Electromagnetic Spectrum

Instructional Days: 20

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 7: The Electromagnetic Spectrum

Instructional Days: 20

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.

Unit 7: The Electromagnetic Spectrum

Instructional Days: 20

What It Looks Like in the Classroom
In this unit of study, students learn that simple waves have repeating patterns with specific wavelengths, frequencies, and amplitudes. They will use both qualitative and quantitative thinking as they describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. For example, students could use a slinky to make a small wave, then increase the energy input and observe that an increase in energy results in an increase in the amplitude of the wave. Or they could push on the surface of a container of water with different amounts of energy and observe the amplitude of the waves created inside the container. Any modeling or demonstrations used to help students visualize this should be followed up with mathematical representations that students could use as evidence to support scientific conclusions about how the amplitude of a wave is related to the energy in a wave. Students can use graphs and charts (teacher provided) to identify patterns in their data. Students will then develop and use models to describe the movement of waves in various materials. Through the use of models and other multimedia and visual displays, students will describe that 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. Students could then broaden their understanding of wave behavior by using models to demonstrate that waves are reflected, absorbed, or transmitted through various materials. Students can observe the behavior of ways by using a penlight and tracing the path that light travels between different transparent materials (e.g., air and water, air and glass. Students could also shine a light through a prism onto a screen or piece of paper, observe a pencil in a glass of water. A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. For example, students could observe some of the wave behaviors or light by observing that when light passes through a small opening the waves spread out. They could observe that if the wavelength is short, the waves spread out very little, whereas longer wavelengths spread out more. Students could them produce sketches of their observations. They may need some guidance in the elaboration of their sketches as it relates to the wave properties of light. Students can use a model of the electromagnetic spectrum to make connections between the brightness and color of light and the frequency of the light. Students will continue their study of waves by observing the behavior of sound waves. Before students begin to study the behavior of sound waves, the teacher could demonstrate the importance of the presence of a medium for sound to travel. For example, if an alarm clock is placed inside a bell jar and the air is removed, the alarm will not be heard outside of the jar. Students could be asked to explain why the can hear the sound before the air is pumped out and not after. This type of demonstration could be followed by discussion of the types of media that sound passes through and how these different media

impacts the sound.

Students could then participate in scientific discussions where they compare the behavior of mechanical waves (sound) and light waves. Based on their observations, students should be able to explain that the amplitude of all waves are related to the energy of the wave and that waves are reflected, absorbed, or transmitted through various materials. They should be able to explain that while mechanical waves need a medium in order to be transmitted, light waves do not. Therefore, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Once students have a clear understanding of how different types of waves behave, they can start to explore how society utilizes those 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. Devices have been designed to utilize properties of waves to serve particular functions. For example, cell phones use wave properties for mobile communication purposes. These devices use digitized signals (sent as wave pulses) because they are a more reliable way than analog signals to encode and transmit information (compare capacity of an LP record to a CD or MP3 player). Another example of this is how digital signals can send information over much longer distances with less loss of information because background noise can be easily converted out by the receiving devices. Wave related technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. Students will 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. Examples include basic understanding that waves can be used for communication purposes including using fiber optic cable to transmit light pulses, radio wave pulses in Wi-Fi devices, and conversation of stored binary patterns to make sound or text on a computer screen.

Unit 7: The Electromagnetic Spectrum

Instructional Days: 20

Connecting with English Language Arts/Literacy and Mathematics
English Language Arts/Literacy • Integrate multimedia and visual displays into presentations that describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave, to clarify information. • Integrate multimedia and visual displays into presentations of a model that describes that waves are reflected, absorbed, or transmitted through various materials to clarify information. • Cite specific textual evidence to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. • Determine the central ideas or conclusions of a text; provide an accurate summary of the text to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals, distinct from prior knowledge or opinions. • Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. • Draw evidence from informational texts to support the analysis of digitized signals as a more reliable way to encode and transmit information than analog signals. • Integrate multimedia and visual displays into presentations to strengthen claims and evidence showing that digitized signals as a more reliable way to encode and transmit information than analog signals. *Mathematics* • Include mathematical representations to describe a simple model for waves. • 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. • Understand the concept of a ratio and use ratio language to describe the relationship between the amplitude of a wave and

the energy in the wave.

- Use ratio and rate reasoning to solve problems showing the relationship between the amplitude of a wave and the energy of the wave.
- Recognize and represent proportional relationships when using mathematical representations to describe a simple model.
- When using mathematical representations to describe a simple model, interpret the equation y = mx + b as defining a linear function whose graph is a straight line and give examples of functions that are not linear.

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
N/A

Unit 7: The Electromagnetic Spectrum

Instructional Days: 20

Prior Learning
By the end of Grade 5, students understand that: • The faster a given object is moving, the more energy it possesses. • Energy can be moved from place to place by moving objects or through sound, light, or electric currents. • Energy is present whenever there are moving objects, sound, light, or heat. • When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. • Light transfers energy from place to place. • Energy can be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by the transformation of energy of motion into electrical energy. • Waves, which are regular patterns of motion, can be made in water by disturbing the surface. • When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. • An object can be seen when light reflected from its surface enters the eyes. • Digitized information can be transmitted over long distances without significant degradation. • High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa.

Unit 7: The Electromagnetic Spectrum

Instructional Days: 20

Future Learning
Physical science • The wavelength and frequency of a wave are related to one another by the speed *P* of the wave, which depends on the type of wave and the medium through which it is passing. • 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. • 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. • 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, by the measured composition of stars and nonstellar gases, and by 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.
- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.
- 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.

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.

Sample of Open Education Resources

Waves on a String: With this simulation (from PHeT), students explore the properties of waves and the behavior of waves through varying mediums and at reflective endpoints. There is a teacher's guide and suggested lessons on related topics that incorporate the simulation.

Sound Waves: Students will learn about frequency, amplitude, how to calculate the speed of sound, and sound waves.

Electromagnetic Math is designed to supplement teaching about electromagnetism. Students explore the simple mathematics behind light and other forms of electromagnetic energy including the properties of waves, wavelength, frequency, the Doppler shift, and the various ways that astronomers image the universe across the electromagnetic spectrum to learn more about the properties of matter and its movement. This collection of 84 problems provides a variety of practical application in mathematics and science concepts including proportions, analyzing graphs, evaluating functions, the inverse-square law, parts of a wave, types of radiation, and energy. Each one-page assignment includes background information. One-page answer keys accompany the assignments.

Unit 7: The Electromagnetic Spectrum

Instructional Days: 20

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** • Develop and use a model to describe	**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)	**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

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)

PS4.B: Electromagnetic Radiation

- 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)

shaped and used. (MS-PS4-2)

- 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)

Unit 7: The Electromagnetic Spectrum

Instructional Days: 20

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 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**	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** 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**

Common Vocabulary	
Conservation	Mass
Convert	Design task
Current	Field
Electric circuit	Insulate
Electric current	Evolve
Transfer	Systematic