Topical Arrangement of the *Next Generation Science Standards*

This arrangement of the *Next Generation Science Standards* (NGSS) is similar to earlier iterations of the standards. At the beginning of the process, in order to eliminate potential redundancy, seek an appropriate grain size, and seek natural connections among the Disciplinary Core Ideas (DCIs) identified within the *Framework for K-12 Science Education*, the writers arranged the DCIs into topics around which to develop the standards. This structure provided the original basis of the standards and has continued through the process.

However, in response to the previous public feedback and direction of the Lead State Partners, **the coding structure of individual performance expectations has changed** to be based on the same DCI arrangement as the *Framework*. The topic names have been retained in order to allow easy comparisons and, where possible, the order of the performance expectations has been retained as well.

Since many states prefer the topical arrangement, and because the writers want to be transparent about changes made from draft to draft, this topic view is once again offered to those who prefer to review the NGSS in this form. Due to the fact that the NGSS progress toward end-of-high school core ideas, the standards may be rearranged in any order.

K.Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment

K.Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment

Students who demonstrate understanding can:

K-LS1-a. **Collect, analyze, and use data to describe patterns of what plants and animals (including humans) need to survive.** [Clarification Statement: Data can come from direct observations and other sources. An example of a pattern is that plants need sunlight and water and animals need food and water. Scientists look for patterns when making observations.] [Assessment Boundary: Survival needs should be limited to food for animals and water and light for plants.]

K-ESS3-a. **Obtain information to describe the relationship between the needs of different plants and animals (including humans) and where they live on the land or in the water.** [Clarification Statement: An example of a relationship is that deer eat grass; therefore, they live in meadows and the forest. Plants, animals, and their surroundings make up a system, and they work together to meet needs.]

K-ESS3-b. **Construct an explanation for how plants and animals (including humans) can change their environment while meeting their basic needs.** [Clarification Statement: An example is a squirrel that digs burrows in the ground to hide its food.] [Assessment Boundary: Students should be able to interpret information provided to them rather than memorizing specific examples.]

K-ESS3-d. **Communicate and discuss solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment using models and/or drawings.*** [Clarification Statement: Students may create real world solutions to use fewer natural resources in the classroom (e.g., reusing classroom materials, recycle water bottles or paper.]

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

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.

- Use and share pictures, drawings and/or writings of observations. (K-LS1-a),(K-ESS3-a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in K-2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.

- Use information from direct or indirect observations to construct explanations. (K-ESS3-b)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.

- Read and comprehend grade-appropriate texts and media to acquire scientific and/or technical information. (K-LS1-a)
- Critique and/or communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers. (K-ESS3-d)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Scientists look for patterns and order when making observations about the world. (K-LS1-a)

Disciplinary Core Ideas

LS1.C: Organization for Matter and Energy Flow in Organisms

- All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow. (K-LS1-a),(K-ESS3-a)

ESS2.E: Biogeology

- Plants and animals (including humans) depend on the land, water, and air to live and grow. They in turn can change their environment (e.g., the shape of land, the flow of water). (K-LS1-a),(K-ESS3-a),(K-ESS3-b)

ESS3.A: Natural Resources

- Living things need water, air, and resources from the land, and they try to live in places that have the things they need. Humans use natural resources for everything they do: for example, they use soil and water to grow food, wood to burn to provide heat or to build shelters, and materials such as iron or copper extracted from the earth to make cooking pans. (K-ESS3-a),(K-ESS3-b)

ESS3.C: Human Impacts on Earth Systems

- Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things—for example, by reducing trash through reuse and recycling. (K-ESS3-d)

Crosscutting Concepts

Patterns

- Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (K-LS1-a)

Cause and Effect

- Events have causes that generate observable patterns. (K-ESS3-b),(K-ESS3-d)

Systems and System Models

- Systems in the natural and designed world have parts that work together. (K-ESS3-a)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.K.3	With prompting and support, describe the connection between two individuals, events, ideas, or pieces of information in a text. (K-ESS3-a)
RI.K.10	Actively engage in group reading activities with purpose and understanding. *(K-LS1-a)*,(K-ESS3-a)
W.K.2	Use a combination of drawing, dictating, and writing to compose informative/explanatory texts in which they name what they are writing about and supply some information about the topic. *(K-LS1-a),(K-ESS3-a),(K-ESS3-b)*,(K-ESS3-d)
W.K.7	Participate in shared research and writing projects (e.g., explore a number of books by a favorite author and express opinions about them). *(K-LS1-a),(K-ESS3-a)*
SL.K.1	Participate in collaborative conversations with diverse partners about kindergarten topics and texts with peers and adults in small and larger groups. *(K-LS1-a),(K-ESS3-a),(K-ESS3-b)*,(K-ESS3-d)
SL.K.3	Add drawings or other visual displays to descriptions as desired to provide additional detail. *(K-LS1-a),(K-ESS3-a),(K-ESS3-b)*,(K-ESS3-d)

Mathematics –

MP.3	Construct viable arguments and critique the reasoning of others. (K-LS1-a),(K-ESS3-a),(K-ESS3-b)
K.CC.4-5	Count to tell the number of objects. *(K-LS1-a),(K-ESS3-a),(K-ESS3-b)*
K.CC.6-7	Compare numbers. *(K-LS1-a),(K-ESS3-a),(K-ESS3-b)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

K.Structure and Properties of Matter

K.Structure and Properties of Matter

Students who demonstrate understanding can:

K-PS1-a. Design and conduct an investigation of different kinds of materials to describe their observable properties and classify the materials based on the patterns observed. [Clarification Statement: Observations are qualitative only and could include relative length, weight, color, texture, and hardness. Patterns include the similar properties that different materials share.]

K-PS1-b. Design and conduct investigations to test the idea that some materials can be a solid or liquid depending on temperature. [Assessment Boundary: Only a qualitative description of temperature should be used such as hot, cool, and warm.]

K-PS1-c. Ask questions, based on observations, to classify different objects by their use and to identify whether they occur naturally or are human-made.* [Clarification Statement: Patterns include the similar characteristics of objects that determine whether they occur naturally or are human-made.]

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

Asking Questions and Defining Problems

Asking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.

- Ask questions based on observations of the natural and/or designed world. (K-PS1-c)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- With guidance, design and conduct investigations in collaboration with peers. (K-PS1-a),(K-PS1-b)
- Make direct or indirect observations and/or measurements to collect data which can be used to make comparisons. (K-PS1-a),(K-PS1-b)

Connections to Nature of Science

Science Knowledge is Based on Empirical Evidence

- Scientists look for patterns and order when making observations about the world. (K-PS1-a),(K-PS1-b),(K-PS1-c)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Different kinds of matter exist (e.g., wood, metal, water) and many of them can be either solid or liquid, depending on temperature. (K-PS1-a),(K-PS1-b)
- Matter can be described and classified by its observable properties (e.g., visual, aural, textural), by its uses, and by whether it occurs naturally or is manufactured. (K-PS1-a),(K-PS1-c)

Crosscutting Concepts

Patterns

- Patterns in the natural and human designed world can be observed, used to describe phenomena and used as evidence. (K-PS1-a),(K-PS1-c)

Cause and Effect

- Events have causes that generate observable patterns. (K-PS1-b)
- Simple tests can be designed to gather evidence to support or refute student ideas about causes. (K-PS1-b)

Connections to Engineering, Technology, and Applications of Science

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

- People depend on various technologies in their lives; human life would be very different without technology. (K-PS1-c)
- Every human-made product is designed by applying some knowledge of the natural world and is built by using materials derived from the natural world, even when the materials are not themselves natural—for example, spoons made from refined metals. (K-PS1-c)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy–

RI.K.1	With prompting and support, ask and answer questions about key details in a text. (K-PS1-c)
W.K.8	With guidance and support from adults, recall information from experiences or gather information from provided sources to answer a question. (K-PS1-c)
SL.K.3	Ask and answer questions in order to seek help, get information, or clarify something that is not understood. (K-PS1-c)

Mathematics –

MP.3	Construct viable arguments and critique the reasoning of others. (K-PS1-b)
K.MD.1	Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object. (K-PS1-a),(K-PS1-b)
K.MD.2	Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference. (K-PS1-a),(K-PS1-b)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

K.Weather and Climate

K.Weather and Climate

Students who demonstrate understanding can:

K-ESS2-a. Observe, record, and share representations of local weather conditions to describe changes over time and identify patterns. [Clarification Statement: Representations may include pictograms, charts, tallies, and drawings. Time can vary from hours to seasons. Scientists look for patterns in their observations. An example of a pattern is that it is usually cooler in the morning than in the afternoon.] [Assessment Boundary: Recording of observations should be limited to qualitative observations.]

K-ESS2-b. Obtain information from text and other media about different types of local weather, including severe weather, and identify the most common types of weather in the local region. [Clarification Statement: Looking for the most common type of weather is looking for a pattern in the recorded data. Scientists use data from others' observations to look for patterns in what has occurred in the past.]

K-ESS3-c. Ask questions and communicate information about the purpose of weather forecasting to prepare for, and respond to, problems caused by weather and how life would be different without forecasts.*

K-PS3-a. Carry out investigations using observations to determine the effect of sunlight on Earth's surface. [Clarification Statement: Examples of Earth's surface could include grass and sand.] [Assessment Boundary: Recording of observations should be limited to qualitative observations of warming effects using a relative scale such as hotter or cooler.]

K-PS3-b. Use tools and materials provided to design and test a structure that will reduce the warming effect of sunlight on Earth's surface.* [Clarification Statement: Students may design simple structures like umbrellas or canopies that minimize the warming effect of the sun by creating shade.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.
- Ask questions based on observations of the natural and/or designed world. (K-ESS3-c)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.
- Make direct or indirect observations and/or measurements to collect data which can be used to make comparisons. (K-PS3-a)

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.
- Use and share pictures, drawings, and/or writings of observations. (K-ESS2-a)
- Use observations to describe patterns and/or relationships in the natural and designed worlds in order to answer scientific questions and solve problems. (K-ESS2-a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.
- Use tools and materials provided to design a device or solution to a specific problem. (K-PS3-b)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.
- Read and comprehend grade-appropriate texts and media to acquire scientific and/or technical information. (K-ESS2-b)
- Critique and/or communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers. (K-ESS3-c)

Connections to Nature of Science

Scientific Investigations Use a Variety of Methods
- Scientist uses different ways to study the world. (K-PS3-a)

Science Knowledge is Based on Empirical Evidence
- Scientists look for patterns and order when making observations about the world. (K-ESS2-a),(K-ESS2-b)

Disciplinary Core Ideas

PS3.B: Conservation of Energy and Energy Transfer
- Sunlight warms Earth's surface. (K-PS3-a),(K-PS3-b)

ESS2.D: Weather and Climate
- Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time. (K-ESS2-a),(K-ESS2-b),(K-PS3-a)

ESS3.B: Natural Hazards
- Some kinds of severe weather are more likely than others in a given region. (K-ESS2-b)
- Weather scientists forecast severe weather so that the communities can prepare for and respond to these events. (K-ESS3-c)

ETS1.A: Defining and Delimiting an Engineering Problem
- Asking questions, making observations, and gathering information are helpful in thinking about problems. (K-ESS3-c),(K-PS3-b)

Crosscutting Concepts

Patterns
- Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (K-ESS2-a),(K-ESS2-b)

Cause and Effect
- Events have causes that generate observable patterns. (K-ESS3-c),(K-PS3-a),(K-PS3-b)
- Simple tests can be designed to gather evidence to support or refute student ideas about causes. (K-PS3-a),(K-PS3-b)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
- People depend on various technologies in their lives; human life would be very different without technology. (K-ESS3-c)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.K.1	With prompting and support, ask and answer questions about key details in a text**.** (K-ESS3-c)
RI.K.3	With prompting and support, describe the connection between two individuals, events, ideas, or pieces of information in a text. (K-ESS2-b)
RI.K.10	Actively engage in group reading activities with purpose and understanding. (K-ESS2-b)
W.K.2	Use a combination of drawing, dictating, and writing to compose informative/explanatory texts in which they name what they are writing about and supply some information about the topic. *(K-ESS2-a)*,(K-ESS3-c)
W.K.7	Participate in shared research and writing projects (e.g., explore a number of books by a favorite author and express opinions about them). *(K-ESS2-b)*
SL.K.1	Participate in collaborative conversations with diverse partners about kindergarten topics and texts with peers and adults in small and larger groups. (K-ESS3-c)
SL.K.3	Ask and answer questions in order to seek help, get information, or clarify something that is not understood. (K-ESS3-c)
SL.K.5	Add drawings or other visual displays to descriptions as desired to provide additional detail. (K-ESS2-a)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

Mathematics –

K.CC.4	Understand the relationship between numbers and quantities; connect counting to cardinality. *(K-ESS2-a)*
K.MD.1	Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object. *(K-ESS2-a),(K-PS3-a)*
K.MD.2	Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference. *(K-ESS2-a),(K-PS3-a)*
K.MD.3	Classify objects into given categories; count the number of objects in each category and sort the categories by count. *(K-ESS2-a),(K-PS3-b),(K-PS3-a)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

1.Structure, Function, and Information Processing

1.Structure, Function, and Information Processing

Students who demonstrate understanding can:

1-LS1-a. Use diagrams and physical models to support the explanation of how the external parts of animals and plants help them survive, grow, and meet their needs. [Clarification Statement: Animals use their parts to seek, find, capture, and eat food, move, grasp objects, sense their environment, and protect themselves. Plants have parts that help them protect themselves, survive, grow, and produce new plants. Models might include drawings, diagrams, or physical replicas.] [Assessment Boundary: Explanations are not expected to include mechanisms, for example, students should be able to connect eyes and how vision helps animals meet their needs.]

1-LS1-b. Define a human problem and design a solution to the problem based on how animals use external parts to meet their own needs.* [Clarification Statement: An example of how humans apply knowledge of the natural world is designing an excavating tool based on animal claws to solve the problem of needing to dig a hole.]

1-LS3-a. Use information from observations to support the explanation that different individual plants and animals of the same type have similarities and differences. [Clarification Statement: Patterns could include similar features that plants or animals share. Examples of observations could include that leaves from the same type of plant are the same shape but can differ in size or a kitten may resemble its parents but is not exactly the same.] [Assessment Boundary: Inheritance is not included.]

1-LS1-c. Record observations and communicate about the ways young plants and animals change as they grow. [Clarification Statement: An example of a pattern could be that young organisms get bigger as they age. Focus is on simple growth and change, not complex life cycles. Information may be obtained from direct observation of organisms as well as various other resources (e.g., books, videos).]

1-LS1-d. Use information from text and other reliable media about the behaviors of parents and offspring and communicate about how those behaviors help offspring survive. [Clarification Statement: Information may be obtained from direct observation as well as various other resources. Patterns could include the signals that offspring make and the responses to the signals of the parents. For example, human babies cry and parents respond by feeding them.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.
- Define a simple problem that can be solved through the development of a new or improved object or tool. (1-LS1-b)

Developing and Using Models
Modeling in K-2 builds on prior experiences and progresses to include identifying, using, and developing models that represent concrete events or design solutions.
- Develop and/or use models (i.e., diagrams, drawings, physical replicas, dioramas, dramatizations, or storyboards) that represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed worlds. (1-LS1-a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.
- Use information from direct or indirect observations to construct explanations. (1-LS3-a)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.
- Read and comprehend grade-appropriate texts and media to acquire scientific and/or technical information. (1-LS1-c),(1-LS1-d)
- Record observations, thoughts, and ideas. (1-LS1-c),(1-LS1-d)

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
- Science uses drawings, sketches, and models as a way to communicate ideas. (1-LS1-a)

Disciplinary Core Ideas

PS4.C: Information Technologies and Instrumentation
- People use their senses to learn about the world around them. Their eyes detect light, their ears detect sound, and they can feel vibrations by touch. (1-LS1-a)

LS1.A: Structure and Function
- All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. (1-LS1-a),(1-LS1-b)
- Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive, grow, and produce more plants. (1-LS1-a)

LS1.B: Growth and Development of Organisms
- Plants and animals have predictable characteristics at different stages of development. Plants and animals grow and change. (1-LS1-c)
- Adult plants and animals can have young. In many kinds of animals, parents and the offspring themselves engage in behaviors that help the offspring to survive. (1-LS1-d)

LS1.D: Information Processing
- Animals have body parts that capture and convey different kinds of information needed for growth and survival—for example, eyes for light, ears for sounds, and skin for temperature or touch. Animals respond to these inputs with behaviors that help them survive (e.g., find food, run from a predator). Plants also respond to some external inputs (e.g., turn leaves toward the sun). (1-LS1-a),(1-LS1-b)

LS2.A: Interdependent Relationships in Ecosystems
- They [animals] use their senses to find food and water, and they use their body parts to gather, catch, eat, and chew the food. (1-LS1-a),(1-LS1-b)

LS3.A: Inheritance of Traits
- Organisms have characteristics that can be similar or different. Young animals are very much, but not exactly, like their parents and also resemble other animals of the same kind. Plants also are very much, but not exactly, like their parents and resemble other plants of the same kind. (1-LS3-a)

LS3.B: Variation of Traits
- Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways. (1-LS3-a)

ETS1.A: Defining and Delimiting an Engineering Problem
- Before beginning to design a solution, it is important to clearly understand the problem. Asking questions, making observations, and gathering information are helpful in thinking about problems. (1-LS1-b)

Crosscutting Concepts

Patterns
- Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (1-LS3-a),(1-LS1-c),(1-LS1-d)

Structure and Function
- The shape and stability of structures of natural and designed objects are related to their function(s). (1-LS1-a),(1-LS1-b)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
- Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. (1-LS1-b)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

1.Structure, Function, and Information Processing

1.Structure, Function, and Information Processing

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.1.10	With prompting and support, read informational texts appropriately complex for grade. *(1-LS1-c)*,(1-LS1-d)
W.1.2	Write informative/explanatory texts in which they name a topic, supply some facts about the topic, and provide some sense of closure. (1-LS1-c),(1-LS1-d)
W.1.7	Participate in shared research and writing projects (e.g., explore a number of "how-to" books on a given topic and use them to write a sequence of instructions). *(1-LS1-c)*,(1-LS1-d)
SL.1.1	Participate in collaborative conversations with diverse partners about grade 1 topics and texts with peers and adults in small and larger groups. (1-LS1-c),(1-LS1-d)
SL.1.5	Add drawings or other visual displays to descriptions when appropriate to clarify ideas, thoughts, and feelings. (1-LS1-c),(1-LS1-d)

Mathematics –

MP.1	Make sense of problems and persevere in solving them. (1-LS1-b)
MP.3	Construct viable arguments and critique the reasoning of others. (1-LS3-a),(1-LS1-d)
1.MD.1	Order three objects by length; compare the lengths of two objects indirectly by using a third object. *(1-LS3-a),(1-LS1-c)*
1.MD.2	Express the length of an object as a whole number of length units, by layering multiple copies of a shorter object (the length unit) end to end; understand that the length measurement of an object is the number of same-size length units that span it with no gaps or overlaps. Limit to contexts where the object being measured is spanned by a whole number of length units with no gaps or overlaps. *(1-LS3-a),(1-LS1-c)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

1.Waves: Light and Sound

1.Waves: Light and Sound

Students who demonstrate understanding can:

1-PS4-b. Construct an explanation using observations as evidence that objects in darkness can be seen only when light travels to the objects and shines on them.

1-PS4-d. Conduct an investigation to determine the effect of placing objects with different characteristics in the path of a beam of light and use these characteristics to meet a goal.* [Clarification Statement: Examples of a goal could include directing light to travel to a desired place or preventing light to travel to a desired place.] [Assessment Boundary: Quantitative measures are not to be assessed.]

1-PS4-c. Record and communicate observations that some very hot objects give off their own light. [Clarification Statement: Students are not expected to have classroom experience with hot objects.]

1-PS4-a. Conduct an investigation to provide evidence that vibrating matter creates sound and that sound can cause matter to vibrate. [Clarification Statement: Examples of vibrating matter that creates sound are tuning forks or plucking a stretched string. An example of how sound can cause matter to vibrate is holding a piece of paper near a speaker.]

1-PS4-e. Use tools and materials to design and build a device that uses light or sound to solve the problem of sending a signal over a distance.* [Clarification Statement: Examples of devices include a light source to send signals, paper cup and string "telephones," or drum beats.] [Assessment Boundary: Technological details for how communication devices work should not be included.]

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

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- Design and conduct investigations collaboratively. (1-PS4-d),(1-PS4-a)
- Make direct or indirect observations and/or measurements to collect data which can be used to make comparisons. (1-PS4-a)
- Make direct or indirect observations and/or measurements of a proposed object or tool or solution to determine if it solves a problem or meets a goal. (1-PS4-d)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.

- Use information from direct or indirect observations to construct explanations. (1-PS4-b)
- Use tools and materials provided to design a device or solution that solves a specific problem. (1-PS4-e)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.

- Record observations, thoughts, and ideas. (1-PS4-c)

Connections to Nature of Science

Scientific Investigations Use a Variety of Methods

- Science investigations begin with a question. (1-PS4-a)
- Science uses different ways to study the world. (1-PS4-a)

Disciplinary Core Ideas

PS4.A: Wave Properties

- Sound can make matter vibrate, and vibrating matter can make sound. (1-PS4-a)

PS4.B: Electromagnetic Radiation

- Objects can be seen only when light is available to illuminate them. Very hot objects give off light (e.g., a fire, the sun). (1-PS4-b),(1-PS4-c)
- Some materials allow light to pass through them, others allow only some light through and others block all the light and create a dark shadow on any surface beyond them (i.e., on the other side from the light source), where the light cannot reach. (1-PS4-d)
- Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.) (1-PS4-d)

PS4.C: Information Technologies and Instrumentation

- People also use a variety of devices to communicate (send and receive information) over long distances. (1-PS4-e)

Crosscutting Concepts

Cause and Effect

- Events have causes that generate observable patterns. (1-PS4-b),(1-PS4-d),(1-PS4-c),(1-PS4-a)
- Simple tests can be designed to gather evidence to support or refute student ideas about causes. (1-PS4-b),(1-PS4-d),(1-PS4-a)

Connections to Engineering, Technology, and Applications of Science

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

- Every human-made product is designed by applying some knowledge of the natural world and is built by using materials derived from the natural world, even when the materials are not themselves natural—for example, spoons made from refined metals. (1-PS4-e)

Interdependence of Science, Engineering, and Technology

- People depend on various technologies in their lives; human life would be very different without technology. (1-PS4-e)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.1.10	With prompting and support, read informational texts appropriately complex for grade. (1-PS4-b),(1-PS4-e)
W.1.2	Write informative/explanatory texts in which they name a topic, supply some facts about the topic, and provide some sense of closure. *(1-PS4-b),*(1-PS4-c)
W.1.7	Participate in shared research and writing projects (e.g., explore a number of "how-to" books on a given topic and use them to write a sequence of instructions). *(1-PS4-d),*(1-PS4-a)
SL.1.1	Participate in collaborative conversations with diverse partners about grade 1 topics and texts with peers and adults in small and larger groups. *(1-PS4-b),*(1-PS4-c)
SL.1.5	Add drawings or other visual displays to descriptions when appropriate to clarify ideas, thoughts, and feelings. *(1-PS4-b),*(1-PS4-c)

Mathematics –

MP.1	Make sense of problems and persevere in solving them. (1-PS4-e)
MP.3	Construct viable arguments and critique the reasoning of others. (1-PS4-b)
1.MD.1	Order three objects by length; compare the lengths of two objects indirectly by using a third object. *(1-PS4-e)*
1.MD.2	Express the length of an object as a whole number of length units, by layering multiple copies of a shorter object (the length unit) end to end; understand that the length measurement of an object is the number of same-size length units that span it with no gaps or overlaps. Limit to contexts where the object being measured is spanned by a whole number of length units with no gaps or overlaps. *(1-PS4-e)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

1.Space Systems: Patterns and Cycles

1.Space Systems: Patterns and Cycles

Students who demonstrate understanding can:

1-ESS1-c. **Record and share observations of locally occurring natural events to identify patterns that are cycles and those that have a clear beginning and end.** [Clarification Statement: Cyclical patterns and patterns that have a clear beginning and end are not mutually exclusive.] [Assessment Boundary: Cycles can include those apparent in the night sky or others covered in first or previous grades.]

1-ESS1-a. **Use observations to describe patterns of objects in the sky that are cyclic and can be predicted.** [Clarification Statement: Examples of patterns include: the sun and moon rise in one part of the sky, appear to move across the sky, and set;, sunrise and sunset times; or stars other than our sun are visible at night but not during the day. Science assumes an order in natural events.]

1-ESS1-b. **Make and share observations about tools to determine if they solve the problem of allowing people to see more objects in the sky and see some objects in greater detail.*** [Clarification Statement: Direct and indirect observations can be obtained using telescopes, binoculars, or reliable media.]

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

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- Make direct or indirect observations and/or measurements of a proposed object or tool or solution to determine if it solves a problem or meets a goal. (1-ESS1-b)

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.

- Use and share pictures, drawings, and/or writings of observations. (1-ESS1-c),(1-ESS1-a)
- Use observations to describe patterns and/or relationships in the natural and designed worlds in order to answer scientific questions and solve problems. (1-ESS1-c),(1-ESS1-a)

Disciplinary Core Ideas

ESS1.A: The Universe and its Stars

- Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. (1-ESS1-a)
- At night one can see the light coming from many stars with the naked eye, but telescopes make it possible to see many more and to observe them and the moon and planets in greater detail. (1-ESS1-b)

ESS1.B: Earth and the Solar System

- Seasonal patterns of sunrise and sunset can be observed, described, and predicted. (1-ESS1-a)

ESS1.C: The History of Planet Earth

- Some events on Earth occur in cycles, like day and night, and others have a beginning and an end, like a volcanic eruption. (1-ESS1-c)

Crosscutting Concepts

Patterns

- Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (1-ESS1-c),(1-ESS1-a)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Science and engineering involve the use of tools to observe and measure things. (1-ESS1-b)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes natural events happen today as they happened in the past. (1-ESS1-a)
- Many events are repeated. (1-ESS1-a)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.1.10	With prompting and support, read informational texts appropriately complex for grade. (1-ESS1-b)
W.1.2	Write informative/explanatory texts in which they name a topic, supply some facts about the topic, and provide some sense of closure. (1-ESS1-c),(1-ESS1-a),(1-ESS1-b)
W.1.7	Participate in shared research and writing projects (e.g., explore a number of "how-to" books on a given topic and use them to write a sequence of instructions). (1-ESS1-b)
SL.1.5	Add drawings or other visual displays to descriptions when appropriate to clarify ideas, thoughts, and feelings. (1-ESS1-c),(1-ESS1-a),(1-ESS1-b)

Mathematics –

MP.7	Look for and make use of structure. (1-ESS1-a)
1.OA.1	Use addition and subtraction within 20 to solve word problems involving situations of adding to, taking from, putting together, taking apart, and comparing, with unknowns in all positions, e.g., by using objects, drawings, and equations to represent the problem. *(1-ESS1-c)*
1.OA.2	Solve word problems that call for addition of three whole numbers whose sum is less than or equal to 20, e.g., by using objects, drawings, and equations to represent the problem. *(1-ESS1-a)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

2.Earth's Surface Systems: Processes that Shape the Earth

2.Earth's Surface Systems: Processes that Shape the Earth

Students who demonstrate understanding can:

2-ESS2-e. Develop and use models to describe patterns of kinds and shapes of landforms and of bodies of water. [Clarification Statement: An example of a pattern might include students using models to compare the shapes of oceans, lakes, and rivers.]

2-ESS2-a. Use observations to construct explanations about how landforms and bodies of water provide homes for living things. [Clarification Statement: Examples of landforms that provide homes are caves used as shelters. An example of cause and effect is a home being created or destroyed as a result of a landform change. Science is how we know about the ways animals live.]

2-ESS2-f. Use observations to construct explanations that water exists in different forms in natural landscapes, determining the variety of life forms that live in a particular location. [Clarification Statement: Students should gather information on the ocean, rivers, lakes, ponds, and moisture in the soil to explain the variety of life in various places, including local areas. An example of the cause and effect relationship is the form of water determining the variety of life forms that can live there.]

2-ESS2-b. Develop models to investigate how wind and water can move Earth materials from one place to another and change the shape of the land quickly or slowly. [Clarification Statement: Examples of changes that occur slowly to shapes of landforms could be sediments built up at the mouth of the river, building and rebuilding of sand dunes, or changes that occur quickly to landforms such as coastal erosion after a hurricane.]

2-ESS2-c. Communicate information about possible design solutions to the loss of homes on land for living things resulting from wind or water resulting in change in the shape of the land.* [Clarification Statement: Students should consider how homes would be replaced and how the homes would change.] [Assessment Boundary: Design that would prevent future loses are not assessed.]

2-ESS2-d. Use drawings and physical models to test, compare strengths and weaknesses, and communicate design solutions that slow or prevent wind and/or water from changing the shape of the land.* [Clarification Statement: Strengths and weaknesses include impacts of design solutions on the natural world.] [Assessment Boundary: Students should be provided a problem in which wind or water could possibly change the shape of the land.]

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

Developing and Using Models

Modeling in K–2 builds on prior experiences and progresses to include identifying, using, and developing models that represent concrete events or design solutions.

- Develop and/or use models (i.e., diagrams, drawings, or physical replicas, dioramas, dramatizations, or storyboards) that represent amounts, relationships, relative scales (bigger, smaller) and/or patterns in the natural and designed worlds. (2-ESS2-e),(2-ESS2-b)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- Make direct or indirect observations and/or measurements to collect data which can be used to make comparisons. (2-ESS2-d)
- Make direct or indirect observations and/or measurements of a proposed object or tool or solution to determine if it solves a problem or meets a goal. (2-ESS2-d)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.

- Use information from direct or indirect observations to construct explanations. (2-ESS2-a),(2-ESS2-f)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.

- Critique and/or communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers. (2-ESS2-c),(2-ESS2-d)
- Record observations, thoughts, and ideas. (2-ESS2-c)

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth

- Some events, like an earthquake, happen very quickly; others, such as the formation of the Grand Canyon, occur very slowly, over a time period much longer than one can observe. (2-ESS2-b)

ESS2.A: Earth Materials and Systems

- Wind and water can change the shape of the land. The resulting landforms, together with the materials on the land, provide homes for living things. (2-ESS2-a),(2-ESS2-b),(2-ESS2-c),(2-ESS2-d)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- Rocks, soils, and sand are present in most areas where plants and animals live. There may also be rivers, streams, lakes, and ponds. Maps show where things are located. One can map the shapes and kinds of land and water in any area. (2-ESS2-e),(2-ESS2-a)

ESS2.C: The Roles of Water in Earth's Surface Processes

- Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. It carries soil and rocks from one place to another and determines the variety of life forms that can live in a particular location. (2-ESS2-f)

ETS1.B: Developing Possible Solutions

- Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. (2-ESS2-d)

ETS1.C: Optimizing the Design Solution

- Because there is always more than one possible solution to a problem, it is useful to compare designs, test them, and discuss their strengths and weaknesses. (2-ESS2-c),(2-ESS2-d)

Crosscutting Concepts

Patterns

- Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (2-ESS2-e)

Cause and Effect

- Events have causes that generate observable patterns. (2-ESS2-a),(2-ESS2-f)
- Simple tests can be designed to gather evidence to support or refute student ideas about causes. (2-ESS2-d)

Stability and Change

- Some things stay the same while other things change. (2-ESS2-b),(2-ESS2-c)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Observations and measurements are also used in engineering to help test and refine design ideas. (2-ESS2-d)

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

- Developing and using technology has impacts on the natural world. (2-ESS2-d)

Connections to Nature of Science

Science is a Way of Knowing

- Science knowledge helps us know about the world. (2-ESS2-a),(2-ESS2-f)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.2.10 By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 2–3 text complexity band proficiently, with scaffolding as needed at the high end of the range. (2-ESS2-e),(2-ESS2-a),(2-ESS2-f)

W.2.2 Write informative/explanatory texts in which they introduce a topic, use facts and definitions to develop points, and provide a concluding statement or section. (2-ESS2-a),(2-ESS2-f),(2-ESS2-c),(2-ESS2-d)

W.2.7 Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations). (2-ESS2-e),(2-ESS2-a),(2-ESS2-f)

SL.2.1 Participate in collaborative conversations with diverse partners about grade 2 topics and texts with peers and adults in small and larger groups. (2-ESS2-a),(2-ESS2-f),(2-ESS2-c),(2-ESS2-d)

SL.2.5 Create audio recordings of stories or poems; add drawings or other visual displays to stories or recounts of experiences when appropriate to clarify ideas, thoughts, and feelings.(2-ESS2-a),(2-ESS2-f),(2-ESS2-c),(2-ESS2-d)

Mathematics –

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

2.Earth's Surface Systems: Processes that Shape the Earth

MP.1	Make sense of problems and persevere in solving them. (2-ESS2-d)
MP.3	Construct viable arguments and critique the reasoning of others. (2-ESS2-a),(2-ESS2-f)
2.NBT.3	Read and write numbers to 1000 using base-ten numerals, number names, and expanded form. *(2-ESS2-a),(2-ESS2-b),(2-ESS2-c)*
2.MD.3	Estimate lengths using units of inches, feet, centimeters, and meters. *(2-ESS2-e),(2-ESS2-b),(2-ESS2-d)*
2.MD.4	Measure to determine how much longer one object is than another, expressing the length difference in terms of a standard length unit. *(2-ESS2-e),(2-ESS2-b)*
2.MD.5	Use addition and subtraction within 100 to solve word problems involving lengths that are given in the same units, e.g., by using drawings (such as drawings of rulers) and equations with a symbol for the unknown number to represent the problem. *(2-ESS2-e),(2-ESS2-b)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

2.Structure and Properties of Matter

2.Structure and Properties of Matter

Students who demonstrate understanding can:

2-PS1-c. Analyze data from tests of a student-designed tool to determine if the tool measures weight or size accurately, compared to standard measuring tools.* [Assessment Boundary: Mass and weight are not distinguished at this grade level.]

2-PS1-b. Design an object built from a small set of pieces to solve a problem and compare solutions designed by peers given the same set of pieces.*

2-PS1-d. Identify arguments that are supported by evidence that some changes caused by heating or cooling can be reversed and some cannot. [Clarification Statement: Examples of reversible changes are melting chocolate or freezing liquids. An irreversible change is cooking food.]

2-PS1-a. Analyze data from testing objects made from different materials to determine if a proposed object functions as intended.* [Clarification Statement: Tests of objects should include the properties of their materials (e.g., strength, flexibility, hardness, texture.]

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

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.
- Analyze data from tests of an object or tool to determine if a proposed object or tool functions as intended. (2-PS1-a), (2-PS1-c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.
- Use tools and materials provided to design a device or solution to a specific problem. (2-PS1-b)
- Generate and compare multiple solutions to a problem. (2-PS1-b)

Engaging in Argument from Evidence
Engaging in argument from evidence in K–2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world.
- Identify arguments that are supported by evidence. (2-PS1-d)

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
- Science searches for cause and effect relationships to explain natural events. (2-PS1-d)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- Different properties are suited to different purposes. (2-PS1-a)
- A great variety of objects can be built up from a small set of pieces (e.g., blocks, construction sets). (2-PS1-b)
- Objects or samples of a substance can be weighed, and their size can be described and measured. (Boundary: volume is introduced only for liquid measure.) (2-PS1-c)

PS1.B: Chemical Reactions
- Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible (e.g., melting and freezing), and sometimes they are not (e.g., baking a cake, burning fuel). (2-PS1-d)

Crosscutting Concepts

Scale, Proportion, and Quantity
- Relative scales allow objects to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower). (2-PS1-d)
- Standard units are used to measure length. (2-PS1-c)

Energy and Matter
- Objects may break into smaller pieces and be put together into larger pieces, or change shapes. (2-PS1-b)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- There are many types of tools produced by engineering that can be used in science to help answer these questions through observation and measurement. (2-PS1-c)
- Science and engineering involve the use of tools to observe and measure things. (2-PS1-c)

Influence of Engineering, Technology, and Science, on Society and the Natural World
- Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. (2-PS1-b),(2-PS1-a)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.2.8	Explain how an author uses reasons and evidence to support particular points in a text, identifying which reasons and evidence support which point(s). (2-PS1-d)
RI.2.10	By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 2–3 text complexity band proficiently, with scaffolding as needed at the high end of the range. (2-PS1-c),(2-PS1-d),(2-PS1-a)
W.2.7	Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations). (2-PS1-c),(2-PS1-a)
W.2.8	Describe how reasons support specific points the author makes in a text. (2-PS1-d)

Mathematics –

MP.3	Construct viable arguments and critique the reasoning of others. (2-PS1-d)
MP.5	Use appropriate tools strategically. (2-PS1-c)
MP.6	Attend to precision. (2-PS1-c)
2.MD.10	Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in a bar graph. *(2-PS1-c),(2-PS1-a)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

2.Interdependent Relationships in Ecosystems

2.Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

2-LS4-a. Make observations about the variety of plants and animals living in an area and identify the specific places they live in order to make comparisons between different areas. [Clarification Statement: Each area can be considered a system and the plants and animals are the parts.] [Assessment Boundary: Students should be given a set of data to analyze and interpret; knowledge of animal and plant names in specific habitats is not required.]

2-LS2-a. Develop and use models to compare how living things depend on their surroundings to meet their needs in the places they live. [Clarification Statement: Animal needs include food, water, air, shelter, and favorable temperature; plant needs include light and water. The plants, animals, and their surroundings make up a system in which the parts depend on each other.]

2-LS2-c. Design a solution to a problem caused when a habitat changes and some of the plants and animals may no longer be able to live there.* [Assessment Boundary: Habitat changes are restricted to one change (e.g., temperature, food, amount of water).]

2-LS2-b. Define a simple problem and test solutions to determine which better fulfills the function of an animal necessary for the reproduction of a flowering plant.* [Clarification Statement: Focus is on plant pollination and seed dispersal by animals. The cause is that some animals will pick up pollen and the effect is that the plant will be pollinated.] [Assessment Boundary: Tasks should include the testing and comparison of up to three solutions.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions.
- Define a simple problem that can be solved through the development of a new or improved object or tool. (2-LS2-b)

Developing and Using Models
Modeling in K-2 builds on prior experiences and progresses to include identifying, using, and developing models that represent concrete events or design solutions.
- Develop and/or use models (i.e., diagrams, drawings, physical replicas, dioramas, dramatizations, or storyboards) that represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed worlds. (2-LS2-a)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.
- Make direct or indirect observations and/or measurements to collect data which can be used to make comparisons. (2-LS4-a),(2-LS2-b)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.
- Use tools and materials provided to design a device or solution that solves a specific problem. (2-LS2-c)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence
- Scientists look for patterns and order when making observations about the world. (2-LS4-a)

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems
- Animals depend on their surroundings to get what they need, including food, water, shelter, and a favorable temperature. Animals depend on plants or other animals for food. (2-LS2-a)
- Plants depend on air, water, minerals (in the soil), and light to grow. (2-LS2-a)
- Animals can move around, but plants cannot, and they often depend on animals for pollination or to move their seeds around. (2-LS2-b)
- Different plants survive better in different settings because they have varied needs for water, minerals, and sunlight. (2-LS2-a)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
- Organisms obtain the materials they need to grow and survive from the environment. Many of these materials come from organisms, and are used again by other organisms. (2-LS2-a)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- The places where plants and animals live often change, sometimes slowly and sometimes rapidly. (2-LS2-c)
- When animals and plants get too hot or too cold, they may die. If they cannot find enough food, water, or air, they may die. (2-LS2-c)

LS2.D: Social Interactions and Group Behavior
- Being part of a group helps animals obtain food, defend themselves, and cope with changes. Groups may serve different functions and vary dramatically in size. (2-LS2-b)

LS4.C: Adaptation
- Living things can survive only where their needs are met. If some places are too hot or too cold or have too little water or food, plants and animals may not be able to live there. (2-LS2-a),(2-LS2-c)

LS4.D: Biodiversity and Humans
- There are many different kinds of living things in any area, and they exist in different places on land and in water. (2-LS4-a)

Crosscutting Concepts

Cause and Effect
- Events have causes that generate observable patterns. (2-LS2-b)

Stability and Change
- Some things stay the same while other things change. (2-LS2-c)

Systems and System Models
- Systems in the natural and designed world have parts that work together. (2-LS4-a),(2-LS2-a)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.2.3	Describe the connection between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text. *(2-LS4-a),(2-LS2-a),(2-LS2-c)*
RI.2.10	By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 2–3 text complexity band proficiently, with scaffolding as needed at the high end of the range. *(2-LS2-a),(2-LS2-c), (2-LS2-b)*
RI.2.9	Compare and contrast the most important points presented by two texts on the same topic. (2-LS4-a),(2-LS2-a)
W.2.7	Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations). *(2-LS4-a),(2-LS2-b)*
SL.2.1	Participate in collaborative conversations with diverse partners about grade 2 topics and texts with peers and adults in small and larger groups. *(2-LS4-a),(2-LS2-a),(2-LS2-c),(2-LS2-b)*

Mathematics –

MP.1	Make sense of problems and persevere in solving them. (2-LS2-c),(2-LS2-b)
2.MD.10	Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in a bar graph. (2-LS4-a)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

2.Forces and Interactions: Pushes and Pulls

2.Forces and Interactions: Pushes and Pulls

Students who demonstrate understanding can:

2-PS2-b. Carry out investigations to provide evidence that an object may stay in one place, move, or change shape when pushed or pulled. [Assessment Boundary: The effects of different strengths and different directions of the pushes and pulls need to be tested independently.]

2-PS2-a. Design and conduct investigations of objects moving at different speeds to compare the change of an object's motion and shape before and after a collision. [Assessment Boundary: Comparisons are qualitative.]

2-PS2-c. Make a claim about the effectiveness of a solution that applies a push or a pull to change the speed or direction of an object to solve a problem.* [Clarification Statement: An example of solution is redirecting a marble to avoid an object.] [Assessment Boundary: Using and explaining friction as a mechanism for change in speed is not included.]

2-PS3-a. Carry out investigations to determine the relationship among friction, motion, and the warming of objects. [Clarification Statement: Investigations should be focused on observations on the interaction between objects (e.g. an object sliding on rough vs. smooth surfaces on a slope).] [Assessment Boundary: Observations of warming are qualitative.]

2-PS3-b. Define a problem caused by either too much or too little friction between two objects and develop solutions that address the problem.* [Clarification Statement: Solutions to change the amount of friction between surfaces might include creating a smoother or rougher surface.]

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

Asking Questions and Defining Problems

Asking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.

- Define a simple problem that can be solved through the development of a new or improved object or tool. (2-PS3-b)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- Design and conduct investigations collaboratively. (2-PS2-b),(2-PS2-a),(2-PS3-a)
- Make direct or indirect observations and/or measurements to collect data which can be used to make comparisons. (2-PS2-a)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.

- Use tools and materials provided to design a device or solution to a specific problem. (2-PS3-b)

Engaging in Argument from Evidence

Engaging in argument from evidence in K–2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world.

- Make a claim about the effectiveness of an object, tool, or solution that is based on relevant evidence. (2-PS2-c)

Connections to Nature of Science

Scientific Investigations Use a Variety of Methods

- Science uses different ways to study the world. (2-PS2-b),(2-PS2-a),(2-PS3-a)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Objects pull or push each other when they collide or are connected. (2-PS2-a)
- Pushes and pulls can have different strengths and directions. (2-PS2-b),(2-PS2-a),(2-PS2-c)
- Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. (2-PS2-b)
- An object sliding on a surface or sitting on a slope experiences a pull due to friction on the object due to the surface that opposes the object's motion. (2-PS3-a),(2-PS3-b)

PS2.B: Types of Interactions

- When objects touch or collide, they push on one another and can change motion or shape. (2-PS2-a)

PS2.C: Stability and Instability in Physical Systems

- Whether an object stays still or moves often depends on the effects of multiple pushes and pulls on it (e.g., multiple players trying to pull an object in different directions). It is useful to investigate what pushes and pulls keep something in place (e.g., a ball on a slope, a ladder leaning on a wall) as well as what makes something change or move. (2-PS2-b)

PS3.C: Relationship Between Energy and Forces

- A bigger push or pull makes things go faster. (2-PS2-c)
- Faster speeds during a collision can cause a bigger change in shape of the colliding objects. (2-PS2-a)

PS3.D: Energy in Chemical Processes and Everyday Life

- When two objects rub against each other this interaction is called friction. Friction between two surfaces can warm both of them (e.g., rubbing hands together). There are ways to reduce the friction between two objects. (2-PS3-a),(2-PS3-b)

ETS1.A: Defining Engineering Problems

- A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. (2-PS3-b)

Crosscutting Concepts

Cause and Effect

- Simple tests can be designed to gather evidence to support or refute student ideas about causes. (2-PS2-a),(2-PS2-b),(2-PS2-c),(2-PS3-a),(2-PS3-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.2.3 Describe the connection between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text. (2-PS3-a)

W.2.1 Write opinion pieces in which they introduce the topic or book they are writing about, state an opinion, supply reasons that support the opinion, use linking words (e.g., *because, and, also*) to connect opinion and reasons, and provide a concluding statement or section. (2-PS2-c)

W.2.2 Write informative/explanatory texts in which they introduce a topic, use facts and definitions to develop points, and provide a concluding statement or section. *(2-PS2-c)*

W.2.7 Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations). (2-PS2-b),(2-PS2-a),(2-PS3-a)

SL.2.1 Participate in collaborative conversations with diverse partners about grade 2 topics and texts with peers and adults in small and larger groups. *(2-PS2-c)*

Mathematics –

MP.1 Make sense of problems and persevere in solving them. (2-PS3-b)

MP.3 Construct viable arguments and critique the reasoning of others. (2-PS3-a)

2.MD.1 Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes. (2-PS2-b),*(2-PS2-a),(2-PS2-c)*

2.MD.2 Measure the length of an object twice, using length units of different lengths for the two measurements; describe how the two measurements relate to the size of the unit chosen. *(2-PS2-b),(2-PS2-a),(2-PS2-c),(2-PS3-a),(2-PS3-b)*

2.MD.3 Estimate lengths using units of inches, feet, centimeters, and meters. *(2-PS2-b),(2-PS2-a),(2-PS2-c),(2-PS3-a),(2-PS3-b)*

2.MD.4 Measure to determine how much longer one object is than another, expressing the length difference in terms of a standard length unit. *(2-PS2-b),(2-PS2-a),(2-PS2-c),(2-PS3-a),(2-PS3-b)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

3.Weather and Climate

3.Weather and Climate

Students who demonstrate understanding can:

3-ESS2-a. **Organize simple weather data sets to record local weather data and identify day-to-day variations, as well as long-term patterns of weather.** [Assessment Boundary: Weather data is limited to temperature, precipitation, and wind direction.]

3-ESS2-b. **Display simple data sets in tables and graphs to describe typical weather conditions expected during a particular season and identify variations over years.** [Clarification Statement: Data at this grade level could include average temperature or precipitation.] [Assessment Boundary: Climate change not to be assessed.]

3-ESS2-c. **Obtain and communicate information about the similarities and differences between weather and climate.**

3-ESS3-a. **Use evidence to evaluate and refine design solutions that reduce the environmental and/or societal impacts of a weather-related hazard.*** [Clarification Statement: Examples of solutions to weather-related hazards are physical models of barriers to prevent flooding.]

3-ESS3-b. **Obtain and communicate information about new and/or improved technologies, developed as a result of increased scientific knowledge of weather or related hazards, which have changed the way people live or interact with one another.*** [Clarification Statement: For example, the discovery that lightning is electricity led to the development of the lightning rod.]

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

Analyzing and Interpreting Data

Analyzing data in 3–5 builds on K–2 and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations.

- Display data in tables and graphs, using digital tools when feasible, to reveal patterns that indicate relationships. (3-ESS2-b)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 3–5 level builds on K–2 and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to compare alternative design solutions.

- Use mathematical thinking and/or computational outcomes to compare alternative solutions to an engineering problem. (3-ESS3-a)
- Organize simple data sets to reveal patterns that suggest relationships. (3-ESS2-a)
- Describe, measure, estimate, and graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems. (3-ESS2-a)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 3-5 builds on prior experiences in K-2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.

- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or design a solution to a problem. (3-ESS3-a)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.

- Compare and/or combine across complex texts and/or other reliable media to acquire appropriate scientific and/or technical information. (3-ESS2-c),(3-ESS3-b)
- Combine information in written text with that contained in corresponding tables, diagrams, and/or charts. (3-ESS2-c),(3-ESS3-b)
- Use multiple sources to generate and communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts. (3-ESS2-c),(3-ESS3-b)

Disciplinary Core Ideas

ESS2.D: Weather and Climate

- Weather is the minute-by-minute to day-by-day variation of the atmosphere's condition on a local scale. Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. (3-ESS2-a),(3-ESS2-b),(3-ESS2-c),(3-ESS3-b)

ESS3.B: Natural Hazards

- A variety of natural hazards result from natural processes (e.g. severe weather, floods, and coastal erosion). Humans cannot eliminate natural hazards but can take steps to reduce their impacts. (Note: This Disciplinary Core Idea can also be found in 4.ESP.) (3-ESS3-a),(3-ESS3-b)

Crosscutting Concepts

Patterns

- Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. (3-ESS2-a),(3-ESS2-b),(3-ESS2-c)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process. (3-ESS3-b)

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

- Over time, people's needs and wants change, as do their demands for new and improved technologies. (3-ESS3-b)
- Engineers improve existing technologies or develop new ones to increase their benefits (e.g., better artificial limbs), decrease known risks (e.g., seatbelts in cars), and meet societal demands (e.g., cell phones). (3-ESS3-a)
- When new technologies become available, they can bring about changes in the way people live and interact with one another. (3-ESS3-b)

Connections to Nature of Science

Science is a Human Endeavor

- Science affects everyday life. (3-ESS3-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.3.1 Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers. (3-ESS3-a)

RI.3.9 Compare and contrast the most important points and key details presented in two texts on the same topic. (3-ESS2-b)

RI.3.10 By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 2–3 text. (3-ESS2-c),(3-ESS3-b)

W.3.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (3-ESS2-c),(3-ESS3-b)

SL.3.4 Report on a topic or text, tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace. (3-ESS2-c), (3-ESS3-b)

Mathematics –

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

3.MD.2	Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units, e.g., by using drawings (such as a beaker with a measurement scale) to represent the problem. (3-ESS2-a)
3.MD.3	Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step "how many more" and "how many less" problems using information presented in bar graphs. (3-ESS2-a),(3-ESS2-b)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

3.Interdependent Relationships in Ecosystems: Environmental Impacts on Organisms

3.Interdependent Relationships in Ecosystems: Environmental Impacts on Organisms

Students who demonstrate understanding can:

3-LS4-d. Analyze and interpret data about changes in the environment of different areas and describe how the changes may affect the organisms that live in the areas. [Clarification Statement: Environmental changes should include changes to landforms, distribution of water, temperature, or availability of resources. The system is a particular area, its components, and how they interact.] [Assessment Boundary: Data may be provided for students.]

3-LS4-e. Use evidence about organisms in their natural habitats to design an artificial habitat in which the organisms can survive well.* [Clarification Statement: Evidence to include needs and characteristics of the organisms. The organisms and their habitat make up a system in which the parts depend on each other.]

3-LS4-a. Analyze and interpret data from fossils to describe the types of organisms that lived long ago and the environments in which they lived and compare them with organisms and environments today. [Clarification Statement: Students can observe fossils, images of fossils, and/or other data.]

3-LS2-a. Use multiple sources to generate and communicate information about the size, stability, and specialization of groups animals may form, and how different types of groups may help the members survive in their natural habitats. [Clarification Statement: Systems are groups of animals.] [Assessment Boundary: Knowledge of specific groups of animals is not required.]

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

Analyzing and Interpreting Data
Analyzing data in 3–5 builds on K–2 and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations.
- Display data in tables and graphs, using digital tools when feasible, to reveal patterns that indicate relationships. (3-LS4-d),(3-LS4-a)
- Use data to evaluate claims about cause and effect. (3-LS4-d)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or design a solution to a problem. (3-LS4-e)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.
- Compare and/or combine across complex texts and/or other reliable media to acquire appropriate scientific and/or technical information. (3-LS2-a)
- Use multiple sources to generate and communicate scientific and/or technical information orally and/or in written formats, including various forms of media, and may include tables, diagrams, and charts. (3-LS2-a)

Disciplinary Core Ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. (3-LS4-d)

LS2.D: Social Interactions and Group Behavior
- Groups can be collections of equal individuals, hierarchies with dominant members, small families, groups of single or mixed gender, or groups composed of individuals similar in age. Some groups are stable over long periods of time; others are fluid, with members moving in and out. Some groups assign specialized tasks to each member; in others, all members perform the same or a similar range of functions. (3-LS2-a)

LS4.A: Evidence of Common Ancestry and Diversity
- Some kinds of plants and animals that once lived on Earth (e.g., dinosaurs) are no longer found anywhere, although others now living (e.g., lizards) resemble them in some ways. (Moved from K-2). (3-LS4-a)
- Fossils provide evidence about the types of organisms (both visible and microscopic) that lived long ago and also about the nature of their environments. Fossils can be compared with one another and to living organisms according to their similarities and differences. (3-LS4-a)

LS4.C: Adaptation
- Changes in an organism's habitat are sometimes beneficial to it and sometimes harmful. (3-LS4-d)
- For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all. (3-LS4-d),(3-LS4-e)

LS4.D: Biodiversity and Humans
- Scientists have identified and classified many plants and animals. Populations of organisms live in a variety of habitats, and change in those habitats affects the organisms living there. Humans, like all other organisms, obtain living and nonliving resources from their environments. (3-LS4-d)

Crosscutting Concepts

Systems and System Models
- A system can be described in terms of its components and their interactions. (3-LS4-d),(3-LS4-e)

Stability and Change
- Some systems appear stable, but over long periods of time will eventually change. (3-LS4-a),(3-LS2-a)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Knowledge of relevant scientific concepts and research findings is important in engineering. (3-LS4-e)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.3.1	Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers. (3-LS4-e)
RI.3.7	Use information gained from illustrations (e.g., maps, photographs) and the words in a text to demonstrate understanding of the text (e.g., where, when, why, and how key events occur). (3-LS2-a)
RI.3.9	Compare and contrast the most important points and key details presented in two texts on the same topic. (3-LS2-a)
RI.3.10	By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 2–3 text complexity band independently and proficiently. (3-LS2-a)
W.3.2	Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (3-LS4-d),(3-LS2-a)
W.3.7	Conduct short research projects that build knowledge about a topic. (3-LS2-a)
W.3.8	With guidance and support from adults, recall information from experiences or gather information from provided sources to answer a question. (3-LS2-a)
SL.3.4	Report on a topic or text, tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace. (3-LS4-d),(3-LS2-a)

Mathematics –

MP.3	Construct viable arguments and critique the reasoning of others. (3-LS4-d),(3-LS2-a)
3.MD.4	Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters. *(3-LS4-d),(3-LS4-a),(3-LS2-a)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

3.Forces and Interactions

3.Forces and Interactions

Students who demonstrate understanding can:

3-PS2-b. Investigate the motion of objects to determine when a consistent pattern can be observed and used to predict future motions in the system. [Clarification Statement: An example of motion with a predictable pattern is a child swinging in a swing. In this example, the student could observe the swing moving at different relative rates depending on where it is in the arc of the swing.]

3-PS2-a. Carry out investigations of the motion of objects to predict the effect of forces on an object in terms of balanced forces that do not change motion and unbalanced forces that change motion. [Clarification Statement: An example is pushing on one side of a box can make it start sliding and pushing on a box from both sides, with equal forces, will not produce any motion at all.] [Assessment Boundary: Limit testing to one variable at a time: number, size, or direction of forces. The size and direction of forces should be qualitative. Gravity is only to be addressed as a force that pulls objects down.]

3-PS2-c. Investigate the effect of electric and magnetic forces between objects not in contact with each other and use the observations to describe their relationships. [Clarification Statement: An example of an electric force could be the force on hair from an electrically charged balloon; an example of a magnetic force could be the force between two magnets. Cause and effect relationships include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.] [Assessment Boundary: Limited to forces produced by objects that can be manipulated by students.]

3-PS2-d. Apply scientific knowledge to design and refine solutions to a problem by using the properties of magnets and the forces between them.* [Clarification Statement: Example problems include constructing a latch to keep a door shut, or creating a device to keep two moving objects from touching each other. Students should understand that the results of investigations about non-contact forces inform design solutions.]

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 3–5 builds from grades K–2 experiences and progresses to specifying qualitative relationships.

- Formulate questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (3-PS2-b),(3-PS2-a),(3-PS2-c)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Design and conduct investigations collaboratively, using fair tests in which variables are controlled and the number of trials considered. (3-PS2-a)
- Make observations and/or measurements, collect appropriate data, and identify patterns that provide evidence for an explanation of a phenomenon or test a design solution. (3-PS2-b),(3-PS2-a),(3-PS2-c)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.

- Apply scientific knowledge to solve design problems. (3-PS2-d)

Connections to Nature of Science

Scientific Investigations Use a Variety of Methods

- Science investigations use a variety of tools and techniques. (3-PS2-b),(3-PS2-a),(3-PS2-c)
- There is not one scientific method. (3-PS2-b),(3-PS2-a),(3-PS2-c)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) (3-PS2-a)
- The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) (3-PS2-b)

PS2.B: Types of Interactions

- Objects in contact exert forces on each other (friction, elastic pushes and pulls). (3-PS2-b)
- Electric, magnetic, and gravitational forces between a pair of objects do not require that the objects be in contact—for example, magnets push or pull at a distance. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-c),(3-PS2-d)

PS2.C: Stability and Instability in Physical Systems

- A system can change as it moves in one direction (e.g., a ball rolling down a hill), shift back and forth (e.g., a swinging pendulum), or go through cyclical patterns (e.g., day and night). (3-PS2-b)
- Examining how the forces on and within the system change as it moves can help explain a system's patterns of change. (3-PS2-a)
- A system can appear to be unchanging when processes within the system are going on at opposite but equal rates. (3-PS2-a)

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships are routinely identified, tested, and used to explain change. (3-PS2-a),(3-PS2-c)

Stability and Change

- Change is measured in terms of differences over time and may occur at different rates. (3-PS2-b)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Tools and instruments (e.g., rulers, balances, thermometers, graduated cylinders, telescopes, microscopes) are used in scientific exploration to gather data and help answer questions about the natural world. Engineering design can develop and improve such technologies. (3-PS2-d)
- Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process. (3-PS2-d)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes consistent patterns in natural systems. (3-PS2-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.3.5	Use text features and search tools (e.g., key words, sidebars, hyperlinks) to locate information relevant to a given topic efficiently. (3-PS2-d)
RI.3.10	By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 2–3 text. (3-PS2-b),(3-PS2-a),(3-PS2-c)
W.3.7	Conduct short research projects that build knowledge about a topic. (3-PS2-b),(3-PS2-a),(3-PS2-c)
SL.3.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly. (3-PS2-b),(3-PS2-a),(3-PS2-c)

Mathematics –

MP.1	Make sense of problems and persevere in solving them. (3-PS2-d)
MP.3	Construct viable arguments and critique the reasoning of others. (3-PS2-a)
MP.7	Look for and make use of structure. (3-PS2-b)
3.MD.2	Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units, e.g., by using drawings (such as a beaker with a measurement scale) to represent the problem. *(3-PS2-b),(3-PS2-a)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

3.Inheritance and Variation of Traits: Life Cycles and Traits

3.Inheritance and Variation of Traits: Life Cycles and Traits

Students who demonstrate understanding can:

3-LS1-a. Construct explanations from evidence that life cycles of plants and animals have similar features and predictable patterns. [Clarification Statement: Changes organisms go through during their life form a pattern and can be used to predict what might happen next in a different organism. Reproduction is addressed as just one part of the process of birth, growth, development, reproduction, and death.] [Assessment Boundary: Plant reproduction is limited to flowering plants. Evidence should be provided.]

3-LS3-a. Use evidence to support explanations that traits are inherited from parents, as well as influenced by the environment, and that organisms have variation in their inherited traits. [Clarification Statement: Patterns are the similarities and differences in traits shared among offspring and their parents or among siblings.] [Assessment Boundary: Environmental influences are limited to amount and quality of nutrition, injuries, learning, and location. The genetic mechanisms of inheritance are not included.]

3-LS4-b. Construct explanations for how differences in characteristics provide an advantage to some individuals in the same species in surviving, finding mates, and reproducing. [Clarification Statement: Examples of cause and effect relationships could be plants with large thorns are less likely to be eaten by predators or peacocks with larger feather displays are more likely to find a mate.]

3-LS4-c. Communicate information about how some characteristics of organisms have been used to inspire the design of technology that meets people's changing needs and wants.* [Clarification Statement: Students could identify technologies across diverse cultures that utilize characteristics of organisms such as sonar, insulated vests, camouflage fatigues, or Velcro.] [Assessment Boundary: The mechanism of production is not included; the focus is on utility only.]

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

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or design a solution to a problem. (3-LS1-a),(3-LS4-b)
- Identify the evidence that supports particular points in an explanation. (3-LS3-a)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.
- Compare and/or combine across complex texts and/or other reliable media to acquire appropriate scientific and/or technical information. (3-LS4-c)
- Use multiple sources to generate and communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts. (3-LS4-c)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence
- Science findings are based on recognizing patterns. (3-LS1-a)

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms
- Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles that include being born (sprouting in plants), growing, developing into adults, reproducing, and eventually dying. (3-LS1-a)

LS3.A: Inheritance of Traits
- Many characteristics of organisms are inherited from their parents. Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. (3-LS3-a)

LS3.B: Variation of Traits
- Offspring acquire a mix of traits from their biological parents. Different organisms vary in how they look and function because they have different inherited information. In each kind of organism there is variation in the traits themselves, and different kinds of organisms may have different versions of the trait. The environment also affects the traits that an organism develops—differences in where they grow or in the food they consume may cause organisms that are related to end up looking or behaving differently. (3-LS3-a)

LS4.B: Natural Selection
- Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing. (3-LS4-b),(3-LS4-c)

Crosscutting Concepts

Patterns
- Similarities and differences in patterns can be used to sort and classify natural phenomena. (3-LS3-a)
- Cyclic patterns of change related to time can be used to make predictions. (3-LS1-a)

Cause and Effect
- Cause and effect relationships are routinely identified, tested, and used to explain change. (3-LS4-b)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
- Over time, people's needs and wants change as do their demands for new and improved technologies. (3-LS4-c)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.3.1 Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers. (3-LS3-a)
RI.3.7 Use information gained from illustrations (e.g., maps, photographs) and the words in a text to demonstrate understanding of the text (e.g., where, when, why, and how key events occur). (3-LS4-c)
RI.3.10 By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 2–3 text complexity band independently and proficiently. (3-LS1-a),(3-LS4-b),(3-LS4-c)
W.3.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (3-LS4-c)
SL.4.4 Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace. (3-LS1-a),(3-LS4-b),(3-LS4-c)

Mathematics –

MP.3 Construct viable arguments and critique the reasoning of others. (3-LS1-a),(3-LS3-a),(3-LS4-b)
MP.7 Look for and make use of structure. (3-LS1-a),(3-LS3-a)
3.MD.3 Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step "how many more" and "how many less" problems using information presented in bar graphs. *(3-LS3-a),(3-LS4-b)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

4.Structure, Function, and Information Processing

4.Structure, Function, and Information Processing

Students who demonstrate understanding can:

4-LS1-a. Use simple models to describe that plants and animals have major internal and external structures, including organs, that support survival, growth, behavior, and reproduction. [Clarification Statement: Examples of structures include thorns, stems, roots stamens, ovaries, heart, brain, skin, or bones.] [Assessment Boundary: Students are responsible for the overall functions of major structures but the mechanisms of how they function within a system are not assessed. Students are not expected to memorize different types of structures but should be able to use information given.]

4-LS1-b. Design, test, and compare solutions that replace or enhance the function of an external animal structure necessary for survival.* [Clarification Statement: Students might compare solutions for mobility based on the strength of different materials used.]

4-LS1-c. Construct models to describe that animals' senses receive different types of information from their environment, process the information in the brain, and respond to the information in different ways. [Clarification Statement: Examples of models could be diagrams or analogies.] [Assessment Boundary: Students are not expected to know the mechanisms by which the brain stores and recalls information, nor the mechanisms of how sensory receptors function.]

4-PS4-c. Conduct an investigation to determine the effects of light source color and properties of the surface illuminated have on the appearance of an object. [Clarification Statement: Variables of light source color and surface properties of the object must be investigated independently.] [Assessment Boundary: Cellular and molecular mechanisms of vision and color perception are not included.]

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

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.

- Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. (4-LS1-c)
- Identify limitations of models. (4-LS1-c)
- Use a simple model to test cause and effect relationships concerning the functioning of a proposed object, tool or process. (4-LS1-a)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Design and conduct investigations collaboratively, using fair tests in which variables are controlled and the number of trials considered. (4-PS4-c)
- Evaluate appropriate methods and tools for collecting data. (4-PS4-c)
- Make observations and/or measurements, collect appropriate data, and identify patterns that provide evidence for an explanation of a phenomenon or test a design solution. (4-PS4-c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.

- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or design a solution to a problem. (4-LS1-b)
- Apply scientific knowledge to solve design problems. (4-LS1-b)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.

- Compare and/or combine across complex texts and/or other reliable media to acquire appropriate scientific and/or technical information. (4-LS1-a)
- Use multiple sources to generate and communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts. (4-LS1-a)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science uses tools and technologies to make accurate measurements and observations. (4-PS4-c)

Disciplinary Core Ideas

PS4.B: Electromagnetic Radiation

- An object can be seen when light reflected from its surface enters the eyes; the color people see depends on the color of the available light sources as well as the properties of the surface. (4-PS4-c)

LS1.A: Structure and Function

- Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (4-LS1-a),(4-LS1-b)

LS1.D: Information Processing

- Different sense receptors are specialized for particular kinds of information, which may be then processed and integrated by the animal's brain, with some information stored as memories. Animals are able to use their perceptions and memories to guide their actions. Some responses to information are instinctive—that is, animals' brains are organized so that they do not have to think about how to respond to certain stimuli. (4-LS1-c)

ETS1.C: Optimizing the Design Solution

- Different solutions need to be tested in order to determine which of them best solves the problem given the criteria and the constraints. (4-LS1-b)

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships are routinely identified, tested, and used to explain change. (4-PS4-c)

Structure and Function

- Substructures have shapes and parts that serve functions. (4-LS1-a),(4-LS1-b),(4-LS1-c)

Connections to Engineering, Technology, and Applications of Science

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

- Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. (4-LS1-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:
ELA/Literacy –

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

4.Structure, Function, and Information Processing

RI.4.9	Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably. (4-LS1-b)
SL.4.4	Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace. (4-LS1-a)
SL.4.5	Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes. (4-LS1-a), (4-LS1-c)
Mathematics –	
MP.1	Make sense of problems and persevere in solving them. (4-LS1-b)
MP.3	Construct viable arguments and critique the reasoning of others. (4-LS1-b)
3.MD.1	Tell and write time to the nearest minute and measure time intervals in minutes. Solve word problems involving addition and subtraction of time intervals in minutes, e.g., by representing the problem on a number line diagram. (4-LS1-b)
3.MD.2	Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units, e.g., by using drawings (such as a beaker with a measurement scale) to represent the problem. (4-LS1-b)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

4.Earth's Surface Systems: Processes that Shape the Earth

4.Earth's Surface Systems: Processes that Shape the Earth

Students who demonstrate understanding can:

4-ESS2-a. Design and conduct fair tests on the effects of water, ice, wind, and vegetation on the relative rate of weathering and erosion. [Clarification Statement: Examples of variables to test are angle of slope in the downhill movement of water, amount of vegetation, speed of wind, rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, or volume of water flow.] [Assessment Boundary: Variables must be tested individually.]

4-ESS2-b. Design solutions to mitigate the effect of the processes of erosion and weathering on local landscapes by brainstorming, testing, refining, and communicating solutions with peers.* [Clarification Statement: Processes of weathering refers to mechanical (physical or biological) weathering.]

4-ESS1-a. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for the changes to landforms over time. [Clarification Statement: An example of evidence from patterns is rock layers with shell embedded fossils above layers with plant fossils and no shells; this evidence indicates a change from marine (or lake) environments to land environments over time.] [Assessment Boundary: Specific knowledge of the mechanism of rock formation is not required. Students are not expected to memorize specific rock formations and layers but should be able to use and interpret information provided.]

4-ESS2-c. Analyze maps showing a variety of Earth's features and the occurrence of geologic hazards to determine the geographic patterns that emerge. [Clarification Statement: Earth's features include mountain ranges, deep ocean trenches, and ocean floor structures. Examples of geologic hazards include volcanoes and earthquakes often found at the boundaries of continents.] [Assessment Boundary: Results of analysis and evaluation are qualitative.]

4-ESS3-b. Use evidence to construct and test a solution for reducing the impacts of geological hazards, under a range of likely conditions, to identify factors that need to be improved.* [Clarification Statement: Geologic hazards include volcanoes and earthquakes. Ranges of conditions could include different strengths of earthquakes and different patterns of volcanic eruptions. Factors could include strength, durability, or flexibility.]

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

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Design and conduct investigations collaboratively, using fair tests in which variables are controlled and the number of trials considered. (4-ESS2-a)

Analyzing and Interpreting Data
Analyzing data in 3–5 builds on K–2 and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations.

- Display data in tables and graphs, using digital tools when feasible, to reveal patterns that indicate relationships. (4-ESS2-c)
- Use data to evaluate claims about cause and effect. (4-ESS2-c)
- Compare data collected by different groups in order to discuss similarities and differences in their findings. (4-ESS2-c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.

- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or design a solution to a problem. (4-ESS2-b),(4-ESS3-b)
- Identify the evidence that supports particular points in an explanation. (4-ESS1-a)

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth

- Earth has changed over time. Understanding how landforms develop, are weathered (broken down into smaller pieces), and erode (get transported elsewhere) can help to infer the history of the current landscape. (4-ESS2-a),(4-ESS2-b)
- Local, regional, and global patterns of rock formations reveal changes over time due to earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed. Patterns of tree rings and ice cores from glaciers can help reconstruct Earth's recent climate history. (4-ESS1-a)

ESS2.A: Earth Materials and Systems

- Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (4-ESS2-a),(4-ESS2-b),(4-ESS1-a)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features where people live and in other areas of Earth. (4-ESS2-c)

ESS2.C: The Roles of Water in Earth's Surface Processes

- The downhill movement of water as it flows to the ocean shapes the appearance of the land. (4-ESS2-a)

ESS2.E: Biogeology

- Living things affect the physical characteristics of their regions (e.g., plants' roots hold soil in place, beaver shelters and human-built dams alter the flow of water, plants' respiration affects the air). Many types of rocks and minerals are formed from the remains of organisms or are altered by their activities. (4-ESS2-a),(4-ESS1-a)

ESS3.B: Natural Hazards

- 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. (Note: This Disciplinary Core Idea can also be found in 3.WC.) (4-ESS3-b)

ETS1.B: Designing Solutions to Engineering Problems

- Research on a problem should be carried out—for example, through Internet searches, market research, or field observations—before beginning to design a solution. An often productive way to generate ideas is for people to work together to brainstorm, test, and refine possible solutions. (4-ESS3-b)
- Testing a solution involves investigating how well it performs under a range of likely conditions. (4-ESS2-b),(4-ESS3-b)
- Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (4-ESS2-b),(4-ESS3-b)

Crosscutting Concepts

Patterns

- Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. (4-ESS1-a),(4-ESS2-c)

Cause and Effect

- Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS2-a)

Connections to Engineering, Technology, and Applications of Science

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

- Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands. (4-ESS2-b),(4-ESS3-b)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes consistent patterns in natural systems. (4-ESS1-a)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

4.Earth's Surface Systems: Processes that Shape the Earth

4.Earth's Surface Processes	
Connections to other DCIs in this grade-level: will be added in future version.	
Articulation of DCIs across grade-levels: will be added in future version.	
Common Core State Standards Connections:	
ELA/Literacy –	
RI.4.1	Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. (4-ESS3-b)
RI.4.7	Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears. (4-ESS2-c),(4-ESS3-b)
RI.4.9	Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably. (4-ESS3-b)
W.4.7	Conduct short research projects that build knowledge through investigation of different aspects of a topic. (4-ESS3-b)
Mathematics –	
MP.1	Make sense of problems and persevere in solving them. (4-ESS2-b),(4-ESS3-b)
MP.3	Construct viable arguments and critique the reasoning of others. (4-ESS1-a)
MP.7	Look for and make use of structure. (4-ESS1-a),(4-ESS2-c)
4.MD.1	Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table. *(4-ESS2-a),(4-ESS2-c)*
4.MD.2	Use the four operations to solve word problems involving distances, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measurements given in a larger unit in terms of a smaller unit. Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale. *(4-ESS2-a),(4-ESS2-b),(4-ESS1-a),(4-ESS2-c)*
4.MD.4	Make a line plot to display a data set of measurements in fractions of a unit (1/2, 1/4, 1/8). Solve problems involving addition and subtraction of fractions by using information presented in line plots. *(4-ESS2-a),(4-ESS2-b),(4-ESS1-a),(4-ESS2-c)*
4.MD.5	Measure angles in whole-number degrees using a protractor. Sketch angles of specified measure. (4-ESS2-a)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

4.Energy

4.Energy

Students who demonstrate understanding can:

4-PS3-a. **Construct an argument using evidence about the relationship between the change in motion and the change in energy of an object.** [Assessment Boundary: No attempt is made to give a precise or quantitative definition of energy. Students should not be assessed on quantitative measures of changes.]

4-PS3-c. **Formulate questions and predict outcomes about the change in energy that can occur between colliding objects and/or magnet interactions.** [Clarification Statement: Emphasis is on the change in the energy, not on the forces, as objects interact.] [Assessment Boundary: Quantitative measurements of energy are beyond the scope of assessment.]

4-PS3-b. **Make observations and collect data to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.** [Assessment Boundary: Quantitative measurements of energy are beyond the scope of assessment.]

4-PS3-d. **Use information from texts and diagrams to communicate that scientists and engineers from diverse backgrounds have applied scientific discoveries to invent technologies to enable humans to transport and store energy for practical use in daily life.*** [Clarification Statement: Examples of technology that allows humans to transport and store energy could include batteries in electrical devices, power grids, and gasoline stations.]

4-PS3-e. **Design, test, and refine a device based on the criterion that it converts energy from one form to another with a given set of constraints to solve a real world problem.*** [Clarification Statement: Examples of devices could include a vehicle that converts electrical energy into motion energy of the vehicle or a passive solar heater that converts light into heat. Examples of constraints could include the materials to be used, the cost of the device, or the time to complete the design.]

4-ESS3-a. **Construct a model using abstract representations and examples to describe differences between renewable and non-renewable sources of energy.***

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 3–5 builds from grades K–2 experiences and progresses to specifying qualitative relationships.
- Formulate questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (4-PS3-c)

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.
- Develop a model using an analogy, example or abstract representation to describe a scientific principle or design solution. (4-ESS3-a)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
- Make observations and/or measurements, collect appropriate data, and identify patterns that provide evidence for an explanation of a phenomenon or test a design solution. (4-PS3-b)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Apply scientific knowledge to solve design problems. (4-PS3-e)

Engaging in Argument from Evidence
Engaging in argument from evidence in 3–5 builds from K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world.
- Construct and/or support scientific arguments with evidence, data, and/or a model. (4-PS3-a)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.
- Combine information in written text with that contained in corresponding tables, diagrams, and/or charts. (4-PS3-d)
- Use multiple sources to generate and communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts. (4-PS3-d)

Disciplinary Core Ideas

PS3.A: Definitions of Energy
- The faster a given object is moving, the more energy it possesses. (4-PS3-a)
- Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (Boundary: At this grade level, no attempt is made to give a precise or complete definition of energy.) (4-PS3-b)

PS3.B: Conservation of Energy and Energy Transfer
- 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. (4-PS3-b)
- Light also transfers energy from place to place. For example, energy radiated from the sun is transferred to the earth by light. When this light is absorbed, it warms Earth's land, air, and water and facilitates plant growth. (4-PS3-b)
- 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. The currents may have been produced to begin with by transforming the energy of motion into electrical energy (e.g., moving water driving a spinning turbine which generates electric currents). (4-PS3-b)

PS3.C: Relationship Between Energy and Forces
- When objects collide, the contact forces transfer energy so as to change the objects' motions. Magnets can exert forces on other magnets or on magnetizable materials, causing energy transfer between them (e.g., leading to changes in motion) even when the objects are not touching. (4-PS3-c)

PS3.D: Energy in Chemical Processes and Everyday Life
- The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use—for example, the stored energy of water behind a dam is released so that it flows downhill and drives a turbine generator to produce electricity. (4-PS3-d)
- It is important to be able to concentrate energy so that it is available for use where and when it is needed. For example, batteries are physically transportable energy storage devices, whereas electricity generated by power plants is transferred from place to place through distribution systems. (4-PS3-d)

ESS3.A: Natural Resources
- All materials, 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. (4-ESS3-a)

ETS1.A: Defining Engineering Problems
- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (4-PS3-e)

Crosscutting Concepts

Energy and Matter
- Energy can be transferred in various ways and between objects. (4-PS3-a),(4-PS3-c),(4-PS3-b),(4-PS3-d),(4-PS3-e)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Science and technology support each other. Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies. (4-PS3-d)

Influence of Science, Engineering and Technology on Society and the Natural World
- Engineers improve existing technologies or develop new ones. (4-PS3-d),(4-PS3-e)

Connections to Nature of Science

Science is a Human Endeavor
- Men and women choose careers as scientists and engineers. (4-PS3-b)
- Most scientists and engineers work in teams. (4-PS3-b)
- Science affects everyday life. (4-PS3-b)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

4.Energy

4.Energy
Connections to other DCIs in this grade-level: will be added in future version.
Articulation of DCIs across grade-levels: will be added in future version.
Common Core State Standards Connections: *ELA/Literacy –* **RI.4.2** Determine the main idea of a text and explain how it is supported by key details; summarize the text. (4-PS3-d) **RI.4.7** Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears. (4-PS3-d) **RI.4.10** By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 4–5 text complexity band proficiently, with scaffolding as needed at the high end of the range. (4-PS3-d) **W.4.1** Write opinion pieces on topics or texts, supporting a point of view with reasons and information. (4-PS3-a) **W.4.2** Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (4-PS3-a),(4-PS3-d) **W.4.7** Conduct short research projects that build knowledge through investigation of different aspects of a topic. *(4-PS3-a)*,(4-PS3-d) **SL.4.1** Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 4 topics and texts, building on others' ideas and expressing their own clearly. (4-PS3-a),(4-PS3-d) **SL.4.4** Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace. (4-PS3-a),(4-PS3-d) **SL.4.5** Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes. (4-ESS3-a) *Mathematics –* **MP.1** Make sense of problems and persevere in solving them. (4-PS3-e) **MP.3** Construct viable arguments and critique the reasoning of others. (4-PS3-a) **4.OA.3** Solve multistep word problems posed with whole numbers and having whole-number answers using the four operations, including problems in which remainders must be interpreted. Represent these problems using equations with a letter standing for the unknown quantity. Assess the reasonableness of answers using mental computation and estimation strategies including rounding. *(4-PS3-a)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

4.Waves

4.Waves

Students who demonstrate understanding can:

4-PS4-a. Develop a model to describe patterns produced by waves in terms of amplitude and wavelength. [Assessment Boundary: The patterns involving amplitude and wavelength are qualitative, not quantitative.]

4-PS4-b. Plan data collection methods and make observations to provide evidence that waves transfer energy to objects. [Clarification Statement: Examples of evidence include corks bobbing up and down, earthquake damage, compression in a slinky, or sound making an object vibrate.] [Assessment Boundary: Observations are qualitative, not quantitative.]

4-PS4-d. Design, refine, and evaluate solutions to the real world problem of encoding, transferring, and decoding information using mechanical waves.* [Clarification Statement: An example of a solution could be drums sending coded information through sound waves. For this example, the constraint is that the solution uses mechanical waves and the criteria are that information is successfully encoded, transferred, and decoded.] [Assessment Boundary: No digital encoding, transferring, or decoding of information is to be assessed.]

4-PS4-e. Obtain information to provide evidence that digital information transmitted and received over distances affects people's lives.* [Clarification Statement: An example of a modern device that transmits and receives digital information is a cell phone.]

Science and Engineering Practices

Developing and Using Models

Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.

- Develop and revise models collaboratively to measure and explain frequent and regular events. (4-PS4-a)
- Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. (4-PS4-a)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Evaluate appropriate methods and tools for collecting data. (4-PS4-b)
- Make observations and/or measurements, collect appropriate data, and identify patterns that provide evidence for an explanation of a phenomenon or test a design solution. (4-PS4-b)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.

- Apply scientific knowledge to solve design problems. (4-PS4-d)
- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the problem. (4-PS4-d)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.

- Obtain and combine information from books and/or other reliable media about potential solutions to a specific design problem. (4-PS4-e)

Disciplinary Core Ideas

PS4.A: Wave Properties

- 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; it does not move in the direction of the wave—observe, for example, a bobbing cork or seabird—except when the water meets the beach. (Note: This grade band endpoint was moved from K–2). (4-PS4-a),(4-PS4-b)
- Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-a)
- Earthquakes cause seismic waves, which are waves of motion in Earth's crust. (4-PS4-b)

PS4.C: Information Technologies and Instrumentation

- Digitized information (e.g., the pixels of a picture) can be stored for future recovery or 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. (4-PS4-d),(4-PS4-e)

Crosscutting Concepts

Patterns

- Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. (4-PS4-a)

Energy and Matter

- Energy can be transferred in various ways and between objects. (4-PS4-b)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Tools and instruments (e.g., rulers, balances, thermometers, graduated cylinders, telescopes, microscopes) are used in scientific exploration to gather data and help answer questions about the natural world. Engineering design can develop and improve such technologies. (4-PS4-e)
- Knowledge of relevant scientific concepts and research findings is important in engineering. (4-PS4-d)

Connections to Nature of Science

Science is a Human Endeavor

- Science affects everyday life. (4-PS4-e)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. (4-PS4-e)
RI.4.7 Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears. *(4-PS4-a),(4-PS4-e)*
RI.4.10 By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 4–5 text complexity band proficiently, with scaffolding as needed at the high end of the range. *(4-PS4-a)*,(4-PS4-e)
W.4.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly. *(4-PS4-e)*
W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic. *(4-PS4-e)*
SL.4.4 Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace. *(4-PS4-e)*
SL.4.5 Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes. (4-PS4-a)

Mathematics –

MP.3 Look for and make use of structure. (4-PS4-a)
4.G.1 Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures. *(4-PS4-a)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

5.Structure and Properties of Matter

5.Structure and Properties of Matter

Students who demonstrate understanding can:

5-PS1-c. Make observations and measurements to identify given materials based on their properties. [Clarification Statement: Examples of materials to be identified could include baking soda and metal. Both qualitative and quantitative measurements and observations should be used.] [Assessment Boundary: Density is not intended as an identifiable property.]

5-PS1-d. Design and conduct investigations on the mixing of two or more different substances to determine whether a new substance with new properties is formed. [Clarification Statement: Examples of interactions forming new substances can include mixing baking soda and vinegar. Examples of interactions not forming new substances can include mixing baking soda and water.]

5-PS1-e. Generate and compare multiple solutions that meet the desired criteria of improving a property of a material within the constraints of changing the type of substances, the amount of substances used to make the material, and the temperature at which they are mixed.*

5-PS1-b. Use simple models to describe that regardless of what reaction or change in properties occur, the total weight of the substances involved does not change.

5-PS1-a. Argue from evidence to support the theory that matter is made of particles too small to be seen. [Clarification Statement: Examples of evidence could include adding air to a basketball, compressing air in a syringe, or moving air on a piece of paper.]

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

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent on events and design solutions.
- Use simple models to describe phenomena concerning the functioning of a natural or designed system. (5-PS1-b)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
- Design and conduct investigations collaboratively, using fair tests in which variables are controlled and the number of trials considered. (5-PS1-d)
- Make observations and/or measurements and identify patterns that provide evidence for an explanation of a phenomenon. (5-PS1-c),(5-PS1-d)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Apply scientific knowledge to solve design problems. (5-PS1-e)
- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the problem. (5-PS1-e)

Engaging in Argument from Evidence
Engaging in argument from evidence in 3–5 builds from K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world.
- Construct and/or support scientific arguments with evidence, data, or a model. (5-PS1-a)
- Compare and refine arguments based on the strengths and weaknesses of the evidence presented. (5-PS1-e)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means (e.g., by weighing or by its effects on other objects). For example, a model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon; the effects of air on larger particles or objects (e.g., leaves in wind, dust suspended in air); and the appearance of visible scale water droplets in condensation, fog, and, by extension, also in clouds or the contrails of a jet. (5-PS1-a)
- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish (e.g., sugar in solution, evaporation in a closed container). (5-PS1-b)
- Measurements of a variety of properties (e.g., hardness, reflectivity) can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.) (5-PS1-c)

PS1.B: Chemical Reactions
- When two or more different substances are mixed, a new substance with different properties may be formed; such occurrences depend on the substances and the temperature. (5-PS1-d),(5-PS1-e)
- No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) (5-PS1-b)

Crosscutting Concepts

Cause and Effect
- Cause and effect relationships are routinely identified, tested, and used to explain change. (5-PS1-d),(5-PS1-e)

Scale, Proportion, and Quantity
- Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume. (5-PS1-c)

Energy and Matter
- Matter is made of particles. (5-PS1-a)
- Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. (5-PS1-b)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science assumes consistent patterns in natural systems. (5-PS1-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:
ELA/Literacy –

RI.5.9	Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (5-PS1-e),(5-PS1-b)
RI.5.10	By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4–5 text complexity band independently and proficiently. (5-PS1-e),(5-PS1-b)
W.5.1	Write opinion pieces on topics or texts, supporting a point of view with reasons and information. (5-PS1-a)
W.5.2	Write informative/explanatory texts to examine a topic and convey ideas and information clearly.(5-PS1-a)
W.5.7	Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. (5-PS1-c),(5-PS1-d)
SL.5.4	Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.(5-PS1-a)

Mathematics –

MP.2	Reason abstractly and quantitatively. (5-PS1-d),(5-PS1-b)
MP.3	Construct viable arguments and critique the reasoning of others. (5-PS1-a)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

5.OA.2	Write and interpret numerical expressions. *(5-PS1-d),(5-PS1-e)*
4.MD.2	Use the four operations to solve word problems involving distances, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measurements given in a larger unit in terms of a smaller unit. Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale. *(5-PS1-d),(5-PS1-e)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

5.Matter and Energy in Organisms and Ecosystems

5.Matter and Energy in Organisms and Ecosystems

Students who demonstrate understanding can:

5-LS2-c. **Use models to test the functioning of a designed process that mitigates a factor upsetting the stability of a local ecosystem.*** [Clarification Statement: Factors that upset an ecosystem's stability include: invasive species, drought, human development, and removal of predators. Models could include simulations, and representations, etc.)

5-LS2-a. **Construct and use models of food webs to describe the transfer of matter among plants, animals, decomposers, and the environment and discuss limitations of these models.** [Clarification Statement: Examples of systems could be: organisms, ecosystems, and the Earth. Matter is transported among and within systems.]

5-PS3-a. **Use models to describe that energy animals use to maintain body warmth, body repair, and for motion was once energy from the sun.** [Clarification Statement: Energy is not transferred by the digestion of food in the digestive system but in the cells after digested food has been absorbed. Care must be taken to avoid creating the misconception that the energy from food is released in the stomach and intestines.]

5-LS2-d. **Ask questions about what organisms obtain from the environment and what they release as waste matter back into the environment.** [Clarification Statement: Air, water, and minerals (fertilizer) are needed by plants but are not food for them; plants use energy from light to make food from non-food, primarily air and water.] [Assessment Boundary: Students should be assessed on the idea that plants make their own food from materials that are not food (air and water), not the process of photosynthesis.]

5-LS2-b. **Formulate questions and predict outcomes about how organisms, such as fungi and bacteria, operate as decomposers to restore (recycle) some materials back to the soil for plants to use in local ecosystems.** [Clarification Statement: Minerals and fertilizer are not food for plants.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades 3–5 builds from grades K–2 experiences and progresses to specifying qualitative relationships.
- Ask questions that relate one variable to another variable. (5-LS2-d)
- Formulate questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (5-LS2-b)

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.
- Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. (5-LS2-a)
- Use simple models to describe phenomena concerning the functioning of a natural system. (5-LS2-a),(5-PS3-a)
- Identify limitations of models. (5-LS2-a)
- Use a simple model to test cause and effect relationships concerning the functioning of a proposed object, tool or process. (5-LS2-c)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence
- Science findings are based on recognizing patterns. (5-LS2-a)

Disciplinary Core Ideas

PS3.D: Energy in Chemical Processes and Everyday Life
- Food and fuel also release energy when they are digested or burned. When machines or animals "use" energy (e.g., to move around), most often the energy is transferred to heat the surrounding environment. (5-PS3-a)
- The energy released by burning fuel or digesting food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). (5-PS3-a)

LS1.C: Organization for Matter and Energy Flow in Organisms
- Animals and plants alike generally need to take in air and water, animals must take in food, and plants need light and minerals. (5-LS2-a)
- Food provides animals with the materials they need for body repair and growth and is digested to release the energy they need to maintain body warmth and for motion. (5-PS3-a)
- Plants acquire their material for growth chiefly from air and water and process matter. (5-LS2-d)

LS2.A: Interdependent Relationships in Ecosystems
- The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. (5-LS2-a)
- Either way, they are "consumers." Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil for plants to use. (5-LS2-b)
- Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem. (5-LS2-c)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
- Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. (5-LS2-a)
- Organisms obtain gases, water, and minerals from the environment, and release waste matter (gas, liquid, or solid) back into the environment. (5-LS2-d)

ETS1.B: Developing Possible Solutions
- There are many types of models, ranging from simple physical models to computer models. They can be used to investigate how a design might work, communicate the design to others, and compare different designs. (5-LS2-c)

Crosscutting Concepts

Systems and System Models
- A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. (5-LS2-c)
- A system can be described in terms of its components and their interactions. (5-LS2-c)

Energy and Matter
- Matter is transported into, out of, and within systems. (5-LS2-a),(5-LS2-d),(5-LS2-b)
- Energy can be transferred in various ways and between objects. (5-PS3-a)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:
ELA/Literacy –

RI.5.9	Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. *(5-LS2-d),(5-LS2-b)*
RI.5.10	By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4–5 text complexity band independently and proficiently. *(5-LS2-c),(5-LS2-a), (5-PS3-a), (5-LS2-d),(5-LS2-b)*
W.5.7	Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. *(5-LS2-d),(5-LS2-b)*
W.5.8	Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources. *(5-LS2-d),(5-LS2-b)*
SL.5.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics and texts*, building on others' ideas and expressing their own clearly. *(5-LS2-d),(5-LS2-b)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

SL.5.5	Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes. (*5-LS2-c),(5-LS2-a),(5-PS3-a)*
Mathematics –	
MP.1	Make sense of problems and persevere in solving them. (5-LS2-c)
MP.3	Construct viable arguments and critique the reasoning of others. (5-LS2-b)
5.MD.1	Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real world problems. *(5-LS2-a)*

5.Earth's Surface Systems

5.Earth's Surface Systems

Students who demonstrate understanding can:

5-ESS2-a. Use models to describe interactions between the geosphere, hydrosphere, atmosphere, and biosphere and identify the limitations of the models. [Clarification Statement: The geosphere, hydrosphere, atmosphere, and biosphere are eacha system.] [Assessment Boundary: Students should only be assessed on the interactions of two systems at a time.]

5-ESS2-b. Use evidence from observations to explain the role of the ocean in supporting ecosystems and their organisms, shaping landforms, and influencing climate. [Clarification Statement: Evidence for supporting ecosystems could include distribution of fish. Evidence for shaping landforms could include pictures of coastal erosion. Evidence for influencing climate could include temperature patterns in coastal vs. continental regions.] [Assessment Boundary: Students should only be assessed on the role of the ocean in supporting ecosystems in general, not on specific ecosystems.]

5-ESS2-c. Develop and revise models to describe how wind and clouds interact with landforms to determine patterns of weather. [Clarification Statement: An example could be when clouds go over mountains, they release their water as precipitation.] [Assessment Boundary: Assessment should not include weather maps.]

5-ESS3-b. Construct explanations for how humans and other organisms will be affected if Earth's temperature continues to rise. [Clarification Statement: Examples of effects on humans and other organisms could include local area changes in crop growing seasons, coral reefs, and habitats for polar organisms.] [Assessment Boundary: The Greenhouse effect and details of climate change are not assessed.]

5-ESS3-a. Design and evaluate a solution to an environmental problem that decreases risks, increases benefits, or better meets societal demands for new or improved technologies.* [Clarification Statement: Examples of solutions could be designing a cost-effective water filtration system that reduces pollutants in a river, conducting an energy audit, and developing a plan to reduce energy use.]

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

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.

- Develop and revise models collaboratively to measure and explain frequent and regular events. (5-ESS2-c)
- Use simple models to describe or support explanations for phenomena and test cause and effect relationships or interactions concerning the functioning of a natural or designed system. (5-ESS2-a)
- Identify limitations of models. (5-ESS2-a)

Analyzing and Interpreting Data
Analyzing data in 3–5 builds on K–2 and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations.

- Use data to evaluate and refine design solutions. (5-ESS3-a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.

- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or design a solution to a problem. (5-ESS2-b),(5-ESS3-b)

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems

- Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. (5-ESS2-a)
- The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. (5-ESS2-b)
- Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-c)
- Human activities affect Earth's systems and their interactions at its surface. (5-ESS3-a)

ESS2.C: The Roles of Water in Earth's Surface Processes

- Water is found almost everywhere on Earth: as vapor; as fog or clouds in the atmosphere; as rain or snow falling from clouds; as ice, snow, and running water on land and in the ocean; and as groundwater beneath the surface. (5-ESS2-a),(5-ESS2-c)
- Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. (5-ESS2-a)

ESS3.C: Human Impacts on Earth Systems

- 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. For example, they are treating sewage, reducing the amounts of materials they use, and regulating sources of pollution such as emissions from factories and power plants or the runoff from agricultural activities. (5-ESS3-a)

ESS3.D: Global Climate Change

- If Earth's global mean temperature continues to rise, the lives of humans and other organisms will be affected in many different ways. (5-ESS3-b)

Crosscutting Concepts

Patterns

- Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. (5-ESS2-c)

Cause and Effect

- Cause and effect relationships are routinely identified, tested, and used to explain change. (5-ESS3-b)

Systems and System Models

- A system can be described in terms of its components and their interactions. (5-ESS2-a),(5-ESS2-b),(5-ESS3-a)

Connections to Engineering, Technology, and Applications of Science

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

- Over time, people's needs and wants change, as do their demands for new and improved technologies. (5-ESS3-a)
- Engineers improve existing technologies or develop new ones to increase their benefits (e.g., better artificial limbs), to decrease known risks (e.g., seatbelts in cars), and to meet societal demands (e.g., cell phones). (5-ESS3-a)

Connections to Nature of Science

Science Addresses Questions About the Natural and Material World.

- Science findings are limited to questions that can be answered with empirical evidence. (5-ESS3-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.5.3	Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text. *(5-ESS2-b),(5-ESS3-b),(5-ESS3-a)*
RI.5.9	Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. *(5-ESS3-b)*
RI.5.10	By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4–5 text complexity band independently and proficiently. *(5-ESS2-b),(5-ESS2-c),(5-ESS3-b),(5-ESS3-a)*
W.5.2	Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (5-ESS3-b)
W.5.7	Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. *(5-ESS2-b), (5-ESS3-b)*
SL.5.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics and texts*, building on others' ideas and expressing their own clearly. *(5-ESS2-b),(5-ESS2-c),(5-ESS3-b),(5-ESS3-a)*
SL.5.2	Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally. (5-ESS3-b)
SL.5.4	Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace. (5-ESS3-b)
SL.5.5	Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

	(5-ESS2-b), (5-ESS3-b)
Mathematics –	
MP.1	Make sense of problems and persevere in solving them. (5-ESS3-a)
MP.3	Construct viable arguments and critique the reasoning of others. (5-ESS2-b),(5-ESS2-c),(5-ESS3-b)
5.G.2	Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation. (5-ESS2-b)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

5.Space Systems: Stars and the Solar System

5.Space Systems: Stars and the Solar System

Students who demonstrate understanding can:

5-PS2-a. **Support an argument that the gravitational force exerted by the Earth on objects near Earth's surface is directed toward the Earth's center.** [Clarification Statement: Support will be drawn from diagrams, evidence, and data that are provided. Earth causes objects to have a force on them that point toward the center of the Earth.] [Assessment Boundary: Mathematical representation of gravitational force is not assessed.]

5-ESS1-a. **Interpret provided data about the relative distances of the sun and other stars from Earth to explain the difference in their apparent brightness.*** [Clarification Statement: Focus on scale is limited to relative distances, not sizes, of stars.] [Assessment Boundary: Other factors that affect apparent brightness (e.g., stellar masses, age, stage) are not assessed.]

5-ESS1-b. **Use a model of the relative positions and motion of the sun, Earth, and moon to describe the observed pattern of daily changes in length and direction of shadows, day and night, and the phases of the moon.*** [Assessment Boundary: Causes of seasons are not to be assessed.]

5-ESS1-c. **Identify evidence that supports explanations for how the position of stars, constellations, and planets in the sky change in consistent patterns as the Earth rotates and orbits the sun along with the other planets.** [Clarification Statement: Evidence consists of information from observations and other sources of the positions of objects in the night sky.] [Assessment Boundary: Performances do not require understanding the mechanism for seasons.]

5-PS4-a. **Apply scientific knowledge of how lenses bend light to design a tool to enhance vision.*** [Clarification Statement: Examples of tools that use lenses include telescopes, binoculars, microscopes, and eyeglasses.] [Assessment Boundary: Quantitative details of refraction not to be included]

5-PS4-b. **Communicate information of how technology has improved over time to increase our ability to see objects and make scientific discoveries about the universe.*** [Assessment Boundary: Students should be able to interpret information that is provided to them rather than memorizing specific examples.]

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

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.
- Use simple models to describe or support explanations for phenomena and test cause and effect relationships or interactions concerning the functioning of a natural or designed system. (5-ESS1-b)

Analyzing and Interpreting Data
Analyzing data in 3–5 builds on K–2 and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations.
- Interpret data to make sense of and explain phenomena, using logical reasoning, mathematics, and/or computation. (5-ESS1-a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Identify the evidence that supports particular points in an explanation. (5-ESS1-c)
- Apply scientific knowledge to solve design problems. (5-PS4-a)

Engaging in Argument from Evidence
Engaging in argument from evidence in 3–5 builds from K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world.
- Construct and/or support scientific arguments with evidence, data, and/or a model. (5-PS2-a)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluate the merit and accuracy of ideas and methods.
- Use multiple sources to generate and communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts. (5-PS4-b)

Connections to Nature of Science

Scientific Knowledge is Open to Revision in Light of New Evidence
- Science explanations can change based on new evidence. (5-PS4-b)

Disciplinary Core Ideas

PS2.B: Types of Interactions
- The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. (5-PS2-a)

PS4.B: Electromagnetic Radiation
- A great deal of light travels through space to Earth from the sun and from distant stars. Because lenses bend light beams, they can be used, singly or in combination, to provide magnified images of objects too small or too far away to be seen with the naked eye. (5-ESS1-a),(5-PS4-a)

PS4.C: Information Technologies and Instrumentation
- Lenses can be used to make eyeglasses, telescopes, or microscopes in order to extend what can be seen. The design of such instruments is based on understanding how the path of light bends at the surface of a lens. (5-PS4-a),(5-PS4-b)

ESS1.A: The Universe and its Stars
- The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their size and distance from Earth. (5-ESS1-a)

ESS1.B: Earth and the Solar System
- The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily and seasonal changes in the length and direction of shadows; phases of the moon; and different positions of the sun, moon, and stars at different times of the day, month, and year. (5-ESS1-b) *(Note: Seasons are addressed in middle school).*
- Some objects in the solar system can be seen with the naked eye. Planets in the night sky change positions and are not always visible from Earth as they orbit the sun. Stars appear in patterns called constellations, which can be used for navigation and appear to move together across the sky because of Earth's rotation. (5-ESS1-c)

Crosscutting Concepts

Patterns
- Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. (5-ESS1-b),(5-ESS1-c)

Cause and Effect
- Cause and effect relationships are routinely identified, tested, and used to explain change. (5-PS2-a)

Scale, Proportion, and Quantity
- Natural objects and observable phenomena exist from the very small to the immensely large. (5-ESS1-a)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Tools and instruments (e.g., rulers, balances, thermometers, graduated cylinders, telescopes, microscopes) are used in scientific exploration to gather data and help answer questions about the natural world. Engineering design can develop and improve such technologies (5-PS4-a),(5-PS4-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.5.3 Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text. (5-ESS1-c),(5-PS4-a),(5-PS4-b)

RI.5.7 Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. (5-PS2-a),(5-PS4-b)

RI.5.8 Explain how an author uses reasons and evidence to support particular points in a text, identifying which reasons and evidence support which point(s). (5-ESS1-a),(5-ESS1-c), (5-PS4-a), (5-PS4-b)

RI.5.10 By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4–5 text

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	complexity band independently and proficiently. (5-PS2-a),(5-ESS1-c),(5-PS4-a)
W.5.1	Write opinion pieces on topics or texts, supporting a point of view with reasons and information. (5-PS2-a)
W.5.2	Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (5-PS4-b)
W.5.7	Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. (5-PS4-b)
SL.5.4	Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace. (5-PS4-b)
Mathematics –	
MP.2	Reason abstractly and quantitatively. (5-ESS1-a)
MP.3	Construct viable arguments and critique the reasoning of others. (5-ESS1-a),(5-PS2-a),(5-ESS1-b),(5-ESS1-c)
5.G.2	Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation. (5-ESS1-b),*(5-ESS1-a),(5-ESS1-c)*

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MS.Structure and Properties of Matter

MS.Structure and Properties of Matter

Students who demonstrate understanding can:

MS-PS1-a. Develop molecular-level models of a variety of substances, comparing those with simple molecules to those with extended structures. [Clarification Statement: Student-provided examples should vary in complexity. Molecular models could include drawings, 3D physical structures or computer representations. Examples of atoms combining could include hydrogen and oxygen combining to form hydrogen peroxide or water, sodium and chlorine to form an extended structure, or carbon to form a diamond. Subunits are atoms (e.g., crystals, metals). An example of subunits could include sodium and chloride, which form crystals.] [Assessment Boundary: Valence electrons and bonding energy are not addressed. When complex structures are made of subunits of ionic natures, discussing the ionic nature of the subunits is not required.]

MS-PS1-b. Design a solution that solves a practical problem by using characteristic chemical and physical properties of pure substances.* [Clarification Statement: Real world problems could involve the need to test for water quality, or mineral content of ores. Properties of substances can include melting and boiling points, density, solubility, reactivity, reaction with oxygen, and phase at a given temperature.] [Assessment Boundary: Limited to simple common substances (e.g., sodium chloride, sugar, sodium bicarbonate, calcium chloride, water, methane, propane, hydrogen, oxygen, steam).]

MS-PS1-c. Develop a molecular level model that depicts and predicts why either temperature change and/or change of state can occur when adding or removing thermal energy from a pure substance. [Clarification Statement: Examples of models can include drawings and diagrams. Examples of pure substances can include water, menthol, or metals.] [Assessment Boundary: The use of mathematical formulas is not intended. Showing that electrostatic interactions break when changing state is not required.]

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Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-PS1-a),(MS-PS1-c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Undertake design projects, engaging in the design cycle, to construct and implement a solution that meets specific design criteria and constraints. (MS-PS1-b)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- All substances are made from some 100 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. (MS-PS1-a)
- Pure substances are made from a single type of atom or molecule. (MS-PS1-a)
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-b)
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-c)
- 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. (MS-PS1-c)
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-a)
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-c)

PS3.A: Definitions of Energy

- The term "heat" as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and to energy transferred between systems by convection, conduction, or radiation (particularly infrared and light). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures. (MS-PS1-c)
- Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (MS-PS1-c)

ETS1.A: Defining and Delimiting an Engineering Problem

- Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (MS-PS1-b)

ETS1.B: Developing Possible Solutions

- There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (MS-PS1-b)

Crosscutting Concepts

Patterns

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-a)

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-c)
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-PS1-c)

Structure and Function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. (MS-PS1-b)

Connections to Engineering, Technology, and Applications of Science

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

- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-PS1-b)
- The uses of technologies are driven by people's 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-PS1-b)

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-PS1-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:
ELA/Literacy –

RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. *(MS-PS1-b)*
RST.6-8.7	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-PS1-c)*
WHST.6-8.7	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-PS1-b)*

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SL.8.1	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-PS1-c)*
SL.7.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. *(MS-PS1-a)*
Mathematics –	
6.EE	Represent and analyze quantitative relationships between dependent and independent variables. *(MS-PS1-b)*
6.SP	Develop understanding of statistical variability (MS-PS1-b)

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MS.Chemical Reactions

MS.Chemical Reactions

Students who demonstrate understanding can:

MS-PS1-d. Develop molecular models of reactants and products to support the explanation that atoms, and therefore mass, are conserved in a chemical reaction. [Clarification Statement: Models can include physical models and drawings that represent atoms rather than symbols. The focus is on law of conservation of matter.] [Assessment Boundary: The use of atomic masses is not required. Balancing symbolic equations (e.g. $N2 + H2 \rightarrow NH3$) is not required.]

MS-PS1-e. Analyze and interpret the properties of products and reactants to determine if a chemical reaction has occurred. [Clarification Statement: Reactions could include burning sugar, mixing vinegar and baking soda, and mixing copper with a weak acid. Properties to analyze are limited to density, melting point, boiling point, states, colors, solubility, flammability, and odor.]

MS-PS1-g. Design, construct, and test a device that either releases or absorbs thermal energy by chemical processes.* [Clarification Statement: Design solutions could involve chemical reactions such as dissolving ammonium chloride, or burning a food item and measuring the temperature of water heated from the reaction.] [Assessment Boundary: Criteria other than temperature and time are not intended in testing the device.]

MS-PS3-f. Develop models to represent that plants produce sugars by reacting carbon dioxide and water and absorbing energy, and that the opposite process occurs in plants and animals to release energy. [Clarification Statement: The focus is on the reciprocal nature of the chemical synthesis and breakdown of sugar and disaccharides in biological systems, using plants and animals as representatives.] [Assessment Boundary: Balancing reactions involving complex organic molecules is not required. Biochemical mechanisms are not addressed.]

MS-PS1-f. Gather and communicate information that people's needs and desires for new materials drive chemistry forward, and that synthetic materials come from natural resources and impact society.* [Clarification Statement: Examples of new materials could include new medicine, foods, and alternative fuels.] [Assessment Boundary: Information obtained should be qualitative.]

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

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-PS1-d),(MS-PS3-f)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Analyze and interpret data in order to determine similarities and differences in findings. (MS-PS1-e)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific knowledge to design, construct, and test a design of an object, tool, process or system. (MS-PS1-g)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.

- Gather, read, and communicate information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used. (MS-PS1-f)

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-PS1-e),(MS-PS3-f)

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

- Laws are regularities or mathematical descriptions of natural phenomena. (MS-PS1-d)

Disciplinary Core Ideas

PS1.B: 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. (MS-PS1-d),(MS-PS1-e),(MS-PS1-f)
- The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-d)
- Some chemical reactions release energy, others store energy. (MS-PS1-g)

PS3.D: Energy in Chemical Processes and Everyday Life

- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (MS-PS3-f)
- Both the burning of fuel and cellular digestion in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (MS-PS3-f)

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-PS1-g)
- There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (MS-PS1-g)

ETS1.C: Optimizing the Design Solution

- Comparing different designs could involve running them through the same kinds of tests and systematically recording the results to determine which design performs best. (MS-PS1-g)
- This 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-PS1-g)

Crosscutting Concepts

Patterns

- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. (MS-PS1-e)
- Graphs and charts can be used to identify patterns in data. (MS-PS1-e)
  - Clarification Statement for MS-PS1-e: Comparing properties is a search for patterns; finding a change in pattern indicates a new substance.

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-d)
- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (MS-PS3-f)
- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS1-g)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-PS1-f)
- In order to design better technologies, new science may need to be explored. (MS-PS1-f)

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-PS1-f)
- The uses of technologies are driven by people's 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-PS1-f)
- Technologies that are beneficial for a certain purpose may later be seen to have impacts that were not foreseen. In such cases, new regulations on used or new technologies may be required. (MS-PS1-f)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

MS.Chemical Reactions

Common Core State Standards Connections:
ELA/Literacy –

RST.6-8.7	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-PS1-d),(MS-PS1-g)*
RI.8.3	Analyze how a text makes connections among and distinctions between individuals, ideas, or events (e.g., through comparisons, analogies, or categories). *(MS-PS1-g)*
SL.7.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. *(MS-PS3-f)*

Mathematics –

MP.2	Reason abstractly and quantitatively. (MS-PS1-e),(MS-PS1-g)
MP.5	Use appropriate tools strategically. *(MS-PS1-g)*
MP.9	Look for and express regularity in repeated reasoning. (MS-PS1-d)
6.EE	Represent and analyze quantitative relationships between dependent and independent variables. *(MS-PS1-e)*
6.SP	Develop understanding of statistical variability. (MS-PS1-e)

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MS.Forces and Interactions

MS.Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-a. **Develop a graphical or physical model, based on Newton's Third Law, to test solutions to a practical problem by predicting the motion of two interacting objects.*** [Clarification Statement: Examples of practical problems could include safety tests on cars that collide with other cars or stationery objects; or the impact of a meteor on a space vehicle.] [Assessment Boundary: Restricted to vertical or horizontal interactions in one dimension.]

MS-PS2-b. **Design an investigation to produce empirical evidence supporting the claim that the change in the motion of an object depends on the sum of the forces on the object and the mass of the object.** [Clarification Statement: This performance expectation addresses both balanced (e.g. Newton's First Law) and unbalanced forces. Both frame of reference and appropriate choice of units should be specified.] [Assessment Boundary: Forces and change in motion are limited to one-dimension. The use of trigonometry is not an expectation. F=m/a is not directly assessed. Only experiments in which one variable is changed are to be assessed. Assessments of measurements of the change in the motion are qualitative.]

MS-PS2-c. **Ask questions about data to clarify the factors that affect the strength of electric and magnetic forces to improve the performance of an electromagnetic device.*** [Clarification Statement: Devices could include electromagnets, electric motors, or generators. Empirical data can include measuring the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [Assessment Boundary: Assessment of Coulomb's Law is not intended.]

MS-PS2-d. **Construct and present oral or written arguments that use evidence to support the claim that gravitational interactions determine the motion of systems of objects in space.** [Clarification Statement: Evidence for arguments can include charts displaying mass, strength of interaction, distance from the sun, orbital periods of objects within the solar system, and various examples of why objects with horizontal velocity fall into the earth versus why satellites don't fall into the earth.] [Assessment Boundary: Quantitative arguments are not assessed. Newton's Law of Gravitation is not assessed. Evidence for arguments is given to students.]

MS-PS2-e. **Design, conduct, and evaluate an investigation that will gather evidence that force fields exist between objects exerting forces on each other, even though the objects are not in contact.** [Clarification Statement: Evaluating an experimental design refers to evaluation of an experiment's ability to provide the data necessary to meet the goals of the experiment. Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, electrically-charged pith balls, and objects at varying distances from the earth or on different planets (which can be investigated through simulations).] [Assessment Boundary: Fields included are limited to gravitational, electric, and magnetic. Determination of fields is qualitative, not quantitative.]

MS-PS2-f. **Define a practical problem that can be solved through the development of a simple system that requires the periodic application of a force initiated by a feedback mechanism to maintain a stable state.*** [Clarification Statement: Examples include a weather vane or a wind sock at an airport.]

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

Asking Questions and Defining Problems

Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable models that support explanations of phenomena or solutions to problems.

- Ask questions to clarify and refine a model, an explanation, or an engineering problem. (MS-PS2-c)
- 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-PS2-f)

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-PS2-a)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Conduct an investigation and evaluate and revise the experimental design to ensure that the data generated can meet the goals of the experiment. (MS-PS2-e)
- Design 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 much data are needed to support the claim. (MS-PS2-b),(MS-PS2-e)

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing

Disciplinary Core Ideas

PS2.A: 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). (MS-PS2-a)
- 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. (MS-PS2-b)
- 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. (MS-PS2-b)
- 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. (MS-PS2-b)

PS2.B: Types of Interactions

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-c)
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (MS-PS2-d)
- Long-range gravitational interactions govern the evolution and maintenance of large-scale systems in space, such as galaxies or the solar system, and determine the patterns of motion within those structures. (MS-PS2-d)
- Forces that act at a distance (gravitational, electric, and magnetic) can be explained by force fields that extend through space and can be mapped by their effect on a test object (a ball, a charged object, or a magnet, respectively). (MS-PS2-e)

PS2.C: Stability and Instability in Physical Systems

- A stable system is one in which any small change results in forces that return the system to its prior state (e.g., a weight hanging from a string). A system can be static but unstable (e.g., a pencil standing on end). (MS-PS2-f)

Crosscutting Concepts

Cause and Effect

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. (MS-PS2-c)
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-c),(MS-PS2-e)

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-PS2-b)
- Scientific relationships can be represented through the use of algebraic expressions and equations. (MS-PS2-b)

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. (MS-PS2-a),(MS-PS2-d),(MS-PS2-e)
- Models are limited in that they only represent certain aspects of the system under study. (MS-PS2-a)

Stability and Change

- Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (MS-PS2-f)

Connections to Engineering, Technology, and Applications of Science

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

- The uses of technologies are driven by people's needs. (MS-PS2-a),(MS-PS2-f)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

argument that supports or refutes claims for either explanations or solutions about the natural and designed world. ▪ Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (MS-PS2-d) --- ***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-PS2-b),(MS-PS2-d) ▪ Science disciplines share common rules of obtaining and evaluating empirical evidence. (MS-PS2-b),(MS-PS2-e)	▪ Many systems, both natural and engineered, rely on feedback mechanisms to maintain stability, but they can function only within a limited range of conditions. With no energy inputs, a system starting out in an unstable state will continue to change until it reaches a stable configuration (e.g., sand in an hourglass). (MS-PS2-f) **ETS1.A: Defining and Delimiting an Engineering Problem** ▪ 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. (MS-PS2-f) **ETS1.B: Developing Possible Solutions** ▪ Models of all kinds are important for testing solutions, and computers are a valuable tool for simulating systems. (MS-PS2-a) ▪ Simulations are useful for predicting what would happen if various parameters of the model were changed, as well as for making improvements to the model based on peer and leader (e.g., teacher) feedback. (MS-PS2-a) **ETS1.C: Optimizing the Design Solution** ▪ Comparing different designs could involve running them through the same kinds of tests and systematically recording the results to determine which design performs best. (MS-PS2-c)	

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RST.6.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (MS-PS2-c),(MS-PS2-e)

Mathematics –

MP 1	Make sense of problems and persevere in solving them (MS-PS2-c)
MP.2	Reason abstractly and quantitatively. (MS-PS2-a), (MS-PS2-b)
MP 4	Model with mathematics (MS-PS2-a)
MP.5	Use appropriate tools strategically. (MS-PS2-c),(MS-PS2-e)
MP.6	Attend to precision. (MS-PS2-d)
5.OA	Analyze patterns and relationships. (MS-PS2-b)
6.RP	Understand ratio concepts and use ratio reasoning to solve problems. (MS-PS2-c)
6.EE	Apply and extend previous understandings of arithmetic to algebraic expressions. (MS-PS2-e)
6.EE.9	Represent and analyze quantitative relationships between dependent and independent variables. (MS-PS2-e)
7.RP	Analyze proportional relationships and use them to solve real-world and mathematical problems. (MS-PS2-c)
7.EE	Solve real-life and mathematical problems using numerical and algebraic expressions and equations. (MS-PS2-b), (MS-PS2-c)
8.EE	Understand the connections between proportional relationships, lines, and linear equations. (MS-PS2-c)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

MS.Energy

Students who demonstrate understanding can:

MS-PS3-a. Construct and interpret graphical displays to describe the relationships between the kinetic energy of an object and its mass, and between the kinetic energy of an object and its speed, in order to better define a real world problem.* [Clarification Statement: Data are provided to students. Examples could include riding a bicycle, rolling a rock downhill, and getting hit by a hardball versus a tennis ball.] [Assessment Boundary: A focus on calculating kinetic energy from the equation is not intended.]

MS-PS3-b. Develop models to describe that when the distance between objects within a system changes, electrical, gravitational, or magnetic fields store different amounts of potential energy. [Clarification Statement: Examples of systems in different configurations could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, an iron nail being moved closer to 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, or written descriptions of systems in different configurations.] [Assessment Boundary: Quantitative calculations are not required.]

MS-PS3-c. Design, construct, and test a device that either minimizes or maximizes thermal energy transfer by conduction, convection, and/or radiation.* [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup. Care should be taken with devices that concentrate significant amounts of energy.] [Assessment Boundary: Quantitative measures of thermal energy transfer are not assessed.]

MS-PS3-d. Design an investigation to determine the relationships among the energy transferred, the type of matter, the amount of sample, and the resulting change in 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. Experiments can be designed individually and collaboratively.] [Assessment Boundary: Calculations of specific heat capacity or thermal energy transferred are not assessed.]

MS-PS3-e. Use and present written arguments that contain evidence to support the claim that when the motion energy of an object changes, energy is transferred to or from the object. [Clarification Statement: Arguments are supported by empirical evidence and reasoning, and can include an inventory or other representations of the energy before and after the transfer. Evidence should be provided to students in the form of temperature changes or motion of object. Students will need to argue conceptually that energy transfers always result in some energy being transferred to the surroundings.] [Assessment Boundary: Calculations of energy are not required. Arguments are qualitative only.]

MS-PS3-g. Modify the design of a machine to improve its efficiency by reducing energy transfer to the surrounding environment.* [Clarification Statement: Energy transfer can include the transfer of energy from motion to thermal energy due to friction. Solutions should focus on the use of advancements in technological and material science to reduce environmental impacts. Familiar machines could include vehicles, bicycles, and pulleys.]

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

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.
- Develop models to describe unobservable mechanisms. (MS-PS3-b)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Design an investigation individually and collaboratively, and in the design: identify independent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how much data are needed to support a claim. (MS-PS3-d)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Construct, analyze, and interpret graphical displays of data to identify linear and nonlinear relationships. (MS-PS3-a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Apply scientific knowledge to design, construct, and test a design of an object, tool, process or system. (MS-PS3-c)
- Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-

Disciplinary Core Ideas

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-a)
- A system of objects may also contain stored (potential) energy, depending on their relative positions. For example, energy is stored—in gravitational interaction with Earth—when an object is raised, and energy is released when the object falls or is lowered. Energy is also stored in the electric fields between charged particles and the magnetic fields between magnets, and it changes when these objects are moved relative to one another. (MS-PS3-b)
- 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-c),(MS-PS3-d)

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. For example, the friction that causes a moving object to stop also results in an increase in the thermal energy in both surfaces; eventually heat energy is transferred to the surrounding environment as the surfaces cool. Similarly, to make an object start moving or to keep it moving when friction forces transfer energy away from it, energy must be provided from, say, chemical (e.g., burning fuel) or electrical (e.g., an electric motor and battery) processes. (MS-PS3-e)
- 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-d)
- Energy is transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation. (MS-PS3-c)

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. For example, when energy is transferred to an Earth-object system as an object is raised, the gravitational field energy of the system increases. This energy is released as the object falls; the mechanism of this release is the gravitational force. Likewise, two magnetic and electrically charged objects interacting at a distance exert forces on each other that can

Crosscutting Concepts

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-a),(MS-PS3-b),(MS-PS3-d)
- Scientific relationships can be represented through the use of algebraic expressions and equations. (MS-PS3-a),(MS-PS3-b)

Energy and Matter
- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-PS3-c),(MS-PS3-e),(MS-PS3-g)
- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS3-c),(MS-PS3-e),(MS-PS3-g)

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testing. (MS-PS3-g) **Engaging in Argument from Evidence** Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world. ▪ Construct, use and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (MS-PS3-e) -- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** ▪ Science knowledge is based upon logical and conceptual connections between evidence and explanations (MS-PS3-d),(MS-PS3-e)	transfer energy between the interacting objects. (MS-PS3-b) **PS3.D: Energy in Chemical Processes and Everyday Life** ▪ Machines can be made more efficient, that is, require less fuel input to perform a given task, by reducing friction between their moving parts and through aerodynamic design. Friction increases energy transfer to the surrounding environment by heating the affected materials. (MS-PS3-g) **ETS1.A: Defining and Delimiting an Engineering Problem** ▪ 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. (MS-PS3-a),(MS-PS3-c) ▪ Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (MS-PS3-a),(MS-PS3-c) **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-PS3-c),(MS-PS3-g) ▪ There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (MS-PS3-c) **ETS1.C: Optimizing the Design Solution** ▪ This 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-PS3-g)	

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. *(MS-PS3-c)*
RST.6-8.7	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-a)*
RI.8.3	Analyze how a text makes connections among and distinctions between individuals, ideas, or events (e.g., through comparisons, analogies, or categories). *(MS-PS3-a)*
WHST.6-8.1	Write arguments focused on discipline content. *(MS-PS3-e)*
WHST.6-8.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. *(MS-PS3-e)*
WHST.6-8.7	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-d)*
WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research. *(MS-PS3-e)*
SL.8.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. *(MS-PS3-b)*

Mathematics –

MP.1	Make sense of problems and persevere in solving them. (MS-PS3-c),(MS-PS3-g)
MP.2	Reason abstractly and quantitatively.(MS-PS3-a),(MS-PS3-b)
MP.5	Use appropriate tools strategically (MS-PS3-a)
5.MD	Represent and interpret data. (MS-PS3-a)
6.RP	Understand ratio concepts and use ratio reasoning to solve problems. *(MS-PS3-a)*
6.EMS-PS3-C	Represent and analyze quantitative relationships between dependent and independent variables. (MS-PS3-a),*(MS-PS3-d)*
6.EMS-PS3-A.1	Write and evaluate numerical expressions involving whole-number exponents. (MS-PS3-a)
6.EMS-PS3-A.2c	Evaluate expressions at specific values of their variables. *(MS-PS3-a)*
7.RP	Analyze proportional relationships and use them to solve real-world and mathematical problems. *(MS-PS3-a)*

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MS.Waves and Electromagnetic Radiation

MS.Waves and Electromagnetic Radiation

Students who demonstrate understanding can:

MS-PS4-a. **Design an investigation to produce data that support the simple model for waves, including how the energy in a wave depends on the amplitude.** [Clarification Statement: The simple model for waves describes waves in terms of wavelength, frequency, and amplitude, and explains what happens when waves pass through each other.] [Assessment Boundary: Electromagnetic waves are not included, only mechanical waves.]

MS-PS4-b. **Develop a model to represent how waves are reflected, absorbed, or transmitted through various materials.** [Clarification Statement: Various materials could include water, glass, metals, or Earth. Lack of a material, a vacuum (bell jar), is also included.] [Assessment Boundary: The assessment should only include qualitative application to light, sound and seismic waves.]

MS-PS4-c. **Analyze and interpret student-generated data to describe the behavior of mechanical waves as they intersect.**

MS-PS4-d. **Construct an explanation, using a wave model of light, for why materials may look different depending on the composition of the material and the wavelength and amplitude of the light that shines on them.** [Assessment Boundary: Qualitative, not quantitative. The assessment is restricted to the following wave properties: frequency, wavelength, and amplitude.]

MS-PS4-e. **Use digital tools and mathematical concepts to compare two or more digital representations of information to determine which represents the optimal tradeoff between performance and cost for a given kind of communication device in a real world context.*** [Clarification Statement: Transmitting information includes detecting, sensing, and interpreting a signal. Performance can be subjectively judged as clarity, sharpness of an image, or length of a text. Advances in digital technology influence the progress of science and science has influenced advances in digital technology.]

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

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.
- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-PS4-b)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Design 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 much data are needed to support their claim. (MS-PS4-a)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Analyze and interpret data in order to determine similarities and differences in findings. (MS-PS4-c)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.
- Use digital tools, mathematical concepts, and arguments to test and compare proposed solutions to an engineering design problem. (MS-PS4-e)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Construct an explanation from models or representations. (MS-PS4-d)

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-a),(MS-PS4-d)

Disciplinary Core Ideas

PS4.A: Wave Properties
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-a)
- A sound wave needs a medium through which it is transmitted. (MS-PS4-b)
- Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (MS-PS4-b)
- [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (MS-PS4-c)

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-b),(MS-PS4-d)
- 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. Lenses and prisms are applications of this effect. (MS-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 (prisms). (MS-PS4-b),(MS-PS4-d)
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-b)

PS4.C: Information Technologies and Instrumentation
- Appropriately designed technologies (e.g., radio, television, cell phones, wired and wireless computer networks) make it possible to detect and interpret many types of signals that cannot be sensed directly. Designers of such devices must understand both the signal and its interactions with matter. (MS-PS4-e)
- Many modern communication devices use digitized signals (sent as wave pulses) as a more reliable way to encode and transmit information. (MS-PS4-e)

ETS1.C: Optimizing the Design Solution
- Once a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful. (MS-PS4-e)

Crosscutting Concepts

Structure and Function
- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. (MS-PS4-a),(MS-PS4-d)
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-b)

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-e)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

Common Core State Standards Connections:
ELA/Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. *(MS-PS4-c)*
RST.6-8.2	Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-PS4-d)
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements or performing technical tasks. (*MS-PS4-a)*
WHST.6-8.2	Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. *(MS-PS4-c),(MS-PS4-d)*
WHST.6-8.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (MS-PS4-c),(MS-PS4-d)
WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research. (MS-PS4-d)
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building others' ideas and expressing their own clearly. *(MS-PS4-d)*
SL.8.4	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-PS4-c),(MS-PS4-d)*
SL.7.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. (MS-PS4-b)

Mathematics –

MP.4	Model with mathematics. *(MS-PS4-a)*
6.EE	Represent and analyze quantitative relationships between dependent and independent variables. *(MS-PS4-a)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

MS.Structure, Function, and Information Processing

MS.Structure, Function, and Information Processing

Students who demonstrate understanding can:

MS-LS1-a. Design and conduct an investigation to provide evidence that living things are made of cells that can be observed at various scales.* [Clarification Statement: Emphasis is on recognizing the strength of evidence from investigations supporting the core idea that living organisms are made of cells. It includes knowledge of ways to observe cells and ways to make observations of the results of cell functions (e.g., carrots becoming crisp when in fresh water but limp in salt water, vegetative reproduction of cutting of a plant). Students should understand that higher scale magnification provides additional information about cells that cannot be seen at lower magnification; and that such discoveries led to medical treatments for diseases such as sickle cell anemia.] [Assessment Boundary: Assessments should provide evidence of students' abilities to identify evidence that living things are made of cells, distinguish between living and not living cells, and explain the interdependence of science, engineering, and technology.]

MS-LS1-b. Design and conduct an investigation to generate evidence that unicellular organisms, like multicellular organisms, survive by obtaining food and water, disposing of waste, and having an environment in which to live. [Clarification Statement: Students can develop and construct investigations that generate evidence for the needs of unicellular organisms (e.g., yeast, pond water organisms). Students can determine which of multiple investigations will provide the best evidence to understand the needs of unicellular organisms as well as limitations of each of the methods presented to them. Students can define the system under investigation and the parts of the system.] [Assessment Boundary: The assessment should provide evidence of students' abilities to describe evidence supporting the concept that unicellular organisms need food, water, waste disposal, and an environment in which to live. The assessment should not investigate the parts of the cell.]

MS-LS1-c. Develop and use models to support explanations about the structure and function relationships in cells and specific parts of the cell (i.e., nucleus, chloroplasts, mitochondria, cell membrane, and cell wall). [Clarification Statement: Emphasis is on the relationship between the function of cell parts and how their function affects the functioning of the cell as a whole.] [Assessment Boundary: The assessment should provide evidence of students' abilities to relate the specific parts of the cells to a function and explain how that part is necessary to maintain the stability of the cell. Assessment is limited to the cell parts listed in the performance expectations and the general function of that part of the cell as it relates to the overall function of the cell.]

MS-LS1-d. Design and conduct an investigation to gather evidence to support explanations that the body is a system of interacting subsystems composed of groups of cells working to form tissues and organs specialized for particular body functions, and that scientific advances in understanding of those systems have led to improvements in nutrition, health, and medicine.* [Clarification Statement: Emphasis is on the interaction of subsystems within a system (i.e., circulatory, excretory, digestive, respiratory, nervous).] [Assessment Boundary: The assessment should provide evidence of students' abilities to identify evidence supporting explanations for the interactions of body systems, and the normal and abnormal functioning of those systems. Assessment should not focus on the mechanism of each body system.]

MS-LS1-l. Construct an explanation by applying scientific knowledge and evidence of how sensory receptors respond to stimuli by sending messages to the brain to be processed for immediate behavior or stored as memories. [Clarification Statement: Emphasis is on explanations on the conceptual level.] [Assessment Boundary: The assessment should provide evidence of students' abilities to provide a basic and conceptual explanation that sensory cells respond to stimuli in the environment and send electrical impulses to the brain where they are processed as ether response or memory.]

MS-LS1-m. Gather, read, and communicate information for how the storage of long-term memories requires changes in the structure and functioning of interconnected nerve cells in the brain. [Clarification Statement: Students can evaluate the source of the information that could be used to obtain reliable information about memory and brain function and communicate a conceptual explanation of the structure function relationships of how the brain is able to store long-term memory.]

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-LS1-c)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Design 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 much data are needed to support their claim. (MS-LS1-d)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (MS-LS1-a), (MS-LS1-b), (MS-LS1-d)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific knowledge and evidence to explain real-world phenomena, examples, or events. (MS-LS1-l)
- Construct explanations from models or

Disciplinary Core Ideas

LS1.A: Structure and Function

- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (MS-LS1-a)
- Unicellular organisms (microorganisms), like multicellular organisms, need food, water, a way to dispose of waste, and an environment in which they can live. (MS-LS1-b)
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (MS-LS1-a),(MS-LS1-c)
- In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. (MS-LS1-d)

LS1.D: Information Processing

- 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. (MS-LS1-l)
- Changes in the structure and functioning of many millions of interconnected nerve cells allow combined inputs to be stored as memories for long periods of time. (MS-LS1-m)

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS1-l)

Scale, Proportion, and Quantity

- Phenomena that can be observed at one scale may not be observable at another scale. (MS-LS1-a)

Systems and System Models

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. (MS-LS1-b)

Structure and Function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. (MS-LS1-c),(MS-LS1-m)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. So science and technology drive each other forward. (MS-LS1-a)

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

- New technologies can have deep impacts on society

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

representations. (MS-LS1-c) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods. ▪ Gather, read, and communicate information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used. (MS-LS1-m)		and the environment, including some that were not anticipated. (MS-LS1-a),(MS-LS1-d) --- ***Connections to Nature of Science*** **Science is a Human Endeavor** ▪ Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. (MS-LS1-d)

Connections to other DCIs in this grade-level: will be added in future versions.

Articulation to DCIs across grade-levels: will be added in future versions.

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. *(MS-LS1-m)*
RST.6-8.2	Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. *(MS-LS1-m)*
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. *(MS-LS1-a),(MS-LS1-b),(MS-LS1-d)*
RST.6-8.7	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-LS1-m)*
RI.6.8	Trace and evaluate the argument and specific claims in a text, distinguishing claims that are supported by reasons and evidence from claims that are not. (MS-LS1-m)
WHST.6-8.2	Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. *(MS-LS1-c),(MS-LS1-l)*
WHST.6-8.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. *(MS-LS1-c),(MS-LS1-l)*
WHST.6-8.8	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 while avoiding plagiarism and providing basic bibliographic information for sources. *(MS-LS1-m)*
WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research. *(MS-LS1-m)*
SL.7.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. *(MS-LS1-c)*

Mathematics –

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

MS.Growth, Development, and Reproduction of Organisms

MS.Growth, Development, and Reproduction of Organisms

Students who demonstrate understanding can:

MS-LS1-i. Construct an explanation using evidence for how environmental and genetic factors affect the growth of organisms. [Clarification Statement: Emphasis is on the impacts of both environmental (e.g., abundance of food, light, space) and genetic factors (e.g., large breed vs. small breed dogs, different species of grasses, different species of trees) on growth of organisms.] [Assessment Boundary: The assessment should measure students' abilities to explain growth differences in terms of both environmental factors and genetic potential.]

MS-LS1-h. Analyze and interpret provided data to generate evidence supporting the explanation that plants may continue to grow throughout their life through the production of new plant matter via photosynthesis. [Clarification Statement: Emphasis is on a conceptual understanding that plant growth continues throughout the life of plants via photosynthesis and not on the details of the mechanisms that enable plants to grow. The data may be from investigations, simulations, or archived data.] [Assessment Boundary: The assessment should measure students' abilities to interpret the data that does or does not support the idea that plants grow throughout their lives via photosynthesis.]

MS-LS3-a. Use a model to support the explanation of how the genetic contribution from each parent through sexual reproduction results in variation in offspring and how asexual reproduction results in offspring with identical genetic information. [Clarification Statement: Emphasis is on using models (e.g., Punnett squares, diagrams, simulations) to explain the cause and effect relationship of gene transmission from parent(s) to offspring and the variation produced.] [Assessment Boundary: The assessment should measure the students' abilities to explain the general outcomes of sexual versus asexual reproduction in terms of variation seen in the offspring.]

MS-LS1-g. Design and conduct an investigation to generate evidence for the role of specialized plant structures in the reproduction of plants, including the role of some animal behaviors resulting in successful plant reproduction. [Clarification Statement: Emphasis is on investigations providing evidence of the mechanisms used by plants to aid reproduction. The mechanisms include specialized plant features (e.g., bright flowers, odors, nectar, sticky seed coats, fruits) and interactions with animals (e.g., bees carrying pollen from plant to plant as they feed, animals eating fruit with seeds).] [Assessment Boundary: The assessment should provide evidence of the students' abilities to match the mechanism with features of the plant. Students should be able to generalize the evidence to multiple plant and animal interactions and why specialized features of plants and animals have co-evolved.]

MS-LS1-e. Construct an argument supported by empirical evidence and scientific reasoning to support an argument for how characteristic animal behaviors affect the probability of successful reproduction. [Clarification Statement: Emphasis is on recognizing or providing evidence for arguments of the cause and effect relationship of specific behaviors contributing to the likelihood of successful reproduction. The probability should be measured in terms of greater or lesser chances of a specific animal behavior being related primarily to reproduction or the meeting of other needs of the animal.] [Assessment Boundary: The assessment should provide evidence of the students' abilities to support arguments for cause and effect relationships between animal behaviors (e.g., nest building, spawning of trout in the late fall, herding, vocalization) and increased probability of successful reproduction.]

MS-LS3-b. Apply scientific knowledge to support the explanation that changes (mutations) to genes located on chromosomes affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. [Clarification Statement: Emphasis is on constructing explanations that genetic mutations can result in harmful, beneficial, or neutral effects to the structure and function of an organism.] [Assessment Boundary: The assessment should provide evidence of students' abilities to communicate the relationship between genetic mutations and variations within a population. The assessment should not require students to describe the changes at the molecular level or any mechanism for protein synthesis.]

MS-LS4-g. Gather, read, and communicate information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.* [Clarification Statement: Emphasis is on evaluating information from reliable sources, about the influence of humans on genetic outcomes (e.g., artificial selection, genetic modification, animal husbandry, gene therapy), and the impact these technologies have had on society as well as the scientific discoveries that have resulted from the technology.] [Assessment Boundary: The assessment should provide evidence of students' abilities to understand and communicate how technology affects both individuals and society.]

MS-LS1-f. Ask questions to clarify the nature of empirical evidence contributing to explanations for the relationship between the behavior of organisms and successful reproduction. [Clarification Statement: Emphasis is on distinguishing science questions that provide empirical evidence to answer questions about behaviors that contribute to successful reproduction from questions that are not scientific or do not contribute to the explanation.] [Assessment Boundary: The assessment should provide evidence of students' abilities to develop logical connections between evidence provided from questioning and explanations for an organism's behavior.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable models that support explanations of phenomena or solutions to problems.

- Ask questions to clarify or identify evidence and the premise(s) of an argument. (MS-LS1-f)
- Formulate a question that can be investigated within the scope of the classroom, school laboratory, or field with available resources and, when appropriate, frame a hypothesis (a possible explanation that predicts a particular and stable outcome) based on a model or theory. (MS-LS1-g)

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to support explanations, describe, test and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-LS3-a)

Planning and Carrying Out Investigations

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (MS-LS3-a)
- Animals engage in characteristic behaviors that increase the odds of reproduction. (MS-LS1-e),(MS-LS1-f)
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features (such as attractively colored flowers) for reproduction. (MS-LS1-g)
- Plant growth can continue throughout the plant's life through production of plant matter in photosynthesis. (MS-LS1-h)
- Genetic factors as well as local conditions affect the size of the adult plant. The growth of an animal is controlled by genetic factors, food intake, and interactions with other organisms, and each species has a typical adult size range. (MS-LS1-i)

LS3.A: Inheritance of Traits

- Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. (MS-LS3-a)
- Each distinct gene chiefly controls the production of

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS1-i),(MS-LS1-h),(MS-LS3-a)
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS1-g),(MS-LS1-e),(MS-LS1-f)

Structure and Function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. (MS-LS3-b)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

MS.Growth, Development, and Reproduction of Organisms

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Design 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 much data are needed to support their claim. (MS-LS1-g)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (MS-LS1-g)
- Evaluate the accuracy of various methods for collecting data. (MS-LS1-g)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Distinguish between causal and correlational relationships. (MS-LS1-h)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific knowledge and evidence to explain real-world phenomena, examples, or events. (MS-LS1-i)
- Base explanations on evidence obtained from sources (including their own experiments) and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (MS-LS3-b)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (MS-LS1-e)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.

- Gather, read, and communicate information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used.

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical connections between evidence and explanations. (MS-LS1-f)

specific proteins, which in turn affects the traits of the individual. (MS-LS3-a)

- Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. (MS-LS3-b)
- Sexual reproduction provides for transmission of genetic information to offspring through egg and sperm cells. These cells, which contain only one chromosome of each parent's chromosome pair, unite to form a new individual (offspring). Thus offspring possess one instance of each parent's chromosome pair (forming a new chromosome pair). Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (MS-LS3-a)

LS3.B: Variation of Traits

- 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. (MS-LS3-a)
- 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. (MS-LS3-b)

LS4.B: Natural Selection

- In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. (MS-LS4-g)

- 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. So science and technology drive each other forward. (MS-LS4-g)

Influence of Engineering, Technology, and Science 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-LS4-g)

Connections to other topics in this grade-level: will be added in future version.

Articulation across grade-levels: will be added in future version.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

MS.Growth, Development, and Reproduction of Organisms

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. *(MS-LS4-g)*
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements or performing technical tasks. *(MS-LS1-g)*
RST.6-8.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics. *(MS-LS4-g)*
RST.6-8.6	Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text. *(MS-LS4-g)*
RST.6-8.7	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-LS1-e),(MS-LS4-g)*
RST.6-8.8	Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. *(MS-LS4-g)*
RI.7.8	Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims. *(MS-LS4-g)*
WHST.6-8.1	Write arguments focused on discipline-specific content. *(MS-LS1-e)*
WHST.6-8.2	Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (MS-LS3-b)
WHST.6-8.7	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-LS1-e)*
WHST.6-8.8	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 follow a standard format for citation. *(MS-LS4-g)*
WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research. *(MS-LS4-g)*
SL.8.1	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-LS1-e)*
SL.8.3	Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced. *(MS-LS1-e)*
SL.6.4	Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation. *(MS-LS3-b)*
SL.7.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. *(MS-LS3-a)*

Mathematics –

MP.1	Make sense of problems and persevere in solving them. (MS-LS1-f)
MP.2	Reason abstractly and quantitatively. (MS-LS3-a)
MP.3	Construct viable arguments and critique the reasoning of others.(MS-LS3-a)
5.OA	Analyze patterns and relationships. (MS-LS1-h),(MS-LS1-g)
6.EE	Represent and analyze quantitative relationships between dependent and independent variables. (MS-LS1-h)

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MS.Matter and Energy in Organisms and Ecosystems

MS.Matter and Energy in Organisms and Ecosystems

Students who demonstrate understanding can:

MS-LS1-j. Base explanations on evidence obtained from sources for the role of photosynthesis in the cycling of matter and flow of energy on Earth. [Clarification Statement: Emphasis is on constructing conceptual explanations of the cycling of matter and flow of energy and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.] [Assessment Boundary: The assessment should provide evidence of students' ability to trace carbon through the carbon cycle and explain that plants use energy from the sun to rearrange the atoms into molecules that have more stored chemical energy. Students should be expected to construct explanations that energy is transferred from plants to animals and relate this to photosynthesis. The assessment should provide evidence that students can construct explanations that energy from the sun is captured by photosynthesis and is then transferred from plants to animals.]

MS-LS2-e. Conduct an investigation of the cycling of matter among living and nonliving parts of ecosystems to support the explanation of the flow of energy and conservation of matter. [Clarification Statement: Emphasis is on students using simulations and models to investigate the cycling of matter and flow of energy. The emphasis is on understanding the conservation of matter. Students can provide explanations that rely on the core idea that matter is conserved and matter cycles. The conservation is explained for both the mass and identity of the atoms involved in the cycling. Students use evidence gathered through the investigation to construct explanations for the movement of matter in living and non-living components of various ecosystems (e.g., ocean, desert, forest, wetland, terrarium) and where the matter is moving in the system.] [Assessment Boundary: The assessment should provide evidence of students' abilities to use data as evidence to support explanations.]

MS-LS2-f. Develop and use a model to support explanations about the transfer of matter and energy into and out of ecosystems and among organisms. [Clarification Statement: Emphasis is on constructing and using models of food webs that include the interactions of producers, consumers, decomposers, and energy sources to explain the transfer of matter and energy among organisms in a variety of ecosystems (e.g., forest, wetland, desert, ocean, terrarium). Emphasis is on only light, chemical, and thermal energy with an emphasis on the concept that the total amount of energy does not change. Students should be able to conceptually describe the movement of carbon, hydrogen and oxygen as it cycles through an ecosystem.] [Assessment Boundary: The assessment should provide evidence of students' abilities to use models (i.e., representations and simulations) to explain the flow of energy and conservation of matter in ecosystems.]

MS-LS1-k. Develop a model to support the explanation that within an individual organism, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules to support growth, or to release energy. [Clarification Statement: Emphasis is on a conceptual understanding of the cycling of food and the release of energy and how it is used in organisms. The energy released from the food is used by the organism for life processes.] [Assessment Boundary: The assessment should provide evidence of students' abilities to use a model to explain the cycling of matter in an organism; the input and output of that matter, and that some of those molecules become part of the organism. Details of cellular respiration or the chemical reactions describing photosynthesis or respiration are not assessed.]

MS-LS2-b. Ask questions to clarify the premise of the argument that organisms within different ecosystems obtain matter and energy in similar ways. [Clarification Statement: Emphasis is on questions that clarify the argument for the similar ways matter and energy are obtained in various ecosystems.] [Assessment Boundary: The assessment should provide evidence of students' ability to pose questions to clarify evidence about obtaining and using matter and energy from an ecosystem and generalize to multiple ecosystems.]

MS-LS2-c. Construct and present arguments supported by empirical evidence and scientific reasoning for multiple explanations for how changes to physical or biological components of an ecosystem result in changes to the populations in the ecosystem.* [Clarification Statement: Emphasis is on the merits of arguments of alternative explanations for what happens to an ecosystem that is altered.] [Assessment Boundary: The assessment should provide evidence of students' abilities to support arguments with scientific evidence that changing physical or biological components in an ecosystem may cause shifts in populations and relative numbers of species in the ecosystem. The assessment should provide evidence of students' abilities to recognize patterns in data and make warranted inferences about changes in populations. The assessment should provide evidence of students' abilities to evaluate evidence that supports multiple explanations for the changes.]

MS-LS2-g. Make an oral or written argument from evidence to support or refute the merits and constraints of different plans to solve a real world problem to restore a disrupted ecosystem.* [Clarification Statement: Emphasis is on distinguishing between effective arguments for merits of competing plans to restore (e.g., remediation plan, reclamation plan, flood control, controlled burns) a disrupted ecosystem.] [Assessment Boundary: The assessment should provide evidence of students' abilities to use systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.]

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

Asking Questions and Defining Problems

Asking questions and defining problems in grades 6-8 builds from grades K-5 experiences and progresses to formulating and refining empirically testable models that support explanations of phenomena or solutions to problems.

- Ask questions to clarify or identify evidence and the premise(s) of an argument. (MS-LS2-b)

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-LS2-f)
- Develop models to describe unobservable mechanisms. (MS-LS2-f),(MS-LS1-k)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Collect data and generate evidence to answer scientific

Disciplinary Core Ideas

LS1.C: Organization for Matter and Energy Flow in Organisms

- Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (MS-LS1-j)
- Animals obtain food from eating plants or eating other animals. (MS-LS1-k)
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth or to release energy. (MS-LS1-k)
- In most animals and plants, oxygen reacts with carbon-containing molecules (sugars) to provide energy and produce carbon-dioxide. (MS-LS2-f)

LS2.A: Interdependent Relationships in Ecosystems

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. 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. (MS-LS2-c)

Crosscutting Concepts

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-LS2-g)

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. (MS-LS2-f)

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-LS2-e),(MS-LS1-k)
- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (MS-LS1-j),(MS-LS2-e),(MS-LS1-k),(MS-LS2-b)
- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-LS1-k)
- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-LS1-j),(MS-LS2-e),(MS-LS1-k)

Stability and Change

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

questions or test design solutions under a range of conditions. (MS-LS2-e)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Base explanations on evidence obtained from sources (including their own experiments) and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (MS-LS1-j)
- Construct explanations from models or representations. (MS-LS2-b)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (MS-LS2-c)
- Make an oral or written argument that refutes the advertised performance of a device, process, or system, based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints. (MS-LS2-g)

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-LS2-c)

Scientific Investigations Use a Variety of Methods

- Science depends on evaluating proposed explanations. (MS-LS2-c)

LS2.B: Cycle of Matter and Energy Transfer in Ecosystems

- Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-b),(MS-LS2-e),(MS-LS2-f),(MS-LS1-k)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- 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. (MS-LS2-c),(MS-LS2-g)

ETS1.B: Developing Possible Solutions

- There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (MS-LS2-g)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-LS2-g)

- Small changes in one part of a system might cause large changes in another part. (MS-LS2-c)

Connections to Nature of Science

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-LS2-c)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. *(MS-LS1-j)*
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements or performing technical tasks. *(MS-LS2-e)*
RST.6-8.6	Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text. *(MS-LS2-b)*
RST.6-8.8	Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. *(MS-LS2-b)*
RI.8.8	Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims. *(MS-LS2-b)*
WHST.6-8.1	Write arguments to support claims with clear reasons and relevant evidence. *(MS-LS2-b) (MS-LS2-c),(MS-LS2-g)*
WHST.6-8.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose and audience. *(MS-LS2-c),(MS-LS2-g)*
WHST.6-8.7	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-LS2-e),(MS-LS2-b)*
WHST.6-8.8	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 while avoiding plagiarism and providing basic bibliographic information for sources. *(MS-LS2-c),(MS-LS2-g)*
WHST.6-8.9	Draw evidence from literary or informational texts to support analysis, reflection, and research. *(MS-LS1-j)*
SL.6.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly. (MS-LS2-c),*(MS-LS2-g)*
SL.6-7.3	Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not. *(MS-LS2-b) (MS-LS2-c),(MS-LS2-g)*
SL.6-7.4	Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation. *(MS-LS2-c),(MS-LS2-g)*
SL.7.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.*(MS-LS2-f),(MS-LS1-k)*

Mathematics –

MP.3	Construct viable arguments and critique the reasoning of others. *(MS-LS2-c),(MS-LS2-g)*
MP.4	Model with mathematics. *(MS-LS2-f)*
5.OA	Analyze patterns and relationships. (MS-LS2-f),(MS-LS2-e),(MS-LS2-b),(MS-LS2-c)
6.SP	Summarize and describe distributions. (MS-LS2-e)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

MS.Interdependent Relationships in Ecosystems

MS.Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

MS-LS2-a. Use a model to support explanations of the effect of resource availability on organisms and populations of organisms in an ecosystem. [Clarification Statement: Emphasis is on cause and effect relationships between resources and populations in ecosystems in terms of changes in the numbers of individuals in the population during periods of abundant resources and scarce resources. Models may include representations of ecosystems and/or graphs and charts showing the flow of matter in food webs or food chains for which students explain the cause and effect of various events and/or conditions.] [Assessment Boundary: The model should focus on organisms' needs and how resources in the ecosystem meet these needs. Determining the carrying capacity of ecosystems is beyond the intent.]

MS-LS2-d. Construct explanations for common patterns of interactions within different ecosystems. [Clarification Statement: Emphasis is on explanations for common patterns of interactions (e.g., competition, predation, parasitism, commensalism, mutualism) that exist in different ecosystems.] [Assessment Boundary: The assessment provides evidence that students can explain the consistency for the interactions of organisms with other organisms and/or the environment across different ecosystems (e.g., ocean, forests, wetlands, deserts, terrariums, cities).]

MS-LS4-i. Use a model of managed ecosystems to evaluate and improve proposals to maintain ecosystem biodiversity.* [Clarification Statement: Emphasis is on providing an explanation for how a more diverse population in an ecosystem adds to the stability of the ecosystem and how humans who engineer and manage ecosystems (e.g., wildlife refuges, national parks, agricultural range lands) need to take biodiversity into account.] [Assessment Boundary: The assessment should provide evidence that students can evaluate various plans and consider the role of biodiversity in the strengths and weaknesses of the plans.]

MS-LS4-j. Use arguments supported by scientific evidence and social and economic rationale to evaluate plans for maintaining biodiversity and ecosystem services.* [Clarification Statement: Emphasis is on determining the best evidence for an argument about biodiversity in light of economic and social considerations in real world situations. Students should be able to determine the evidence that is consistent with science and evidence based on economic and/or social considerations. Focus is on how humans benefit from health ecosystems (e.g., food, energy, medicines).] [Assessment Boundary: Consideration of ecosystem services for humans may include but is not limited to water purification and recycling.]

MS-LS2-h. Ask questions to clarify how patterns of social interactions and grouping behaviors contribute to a survival advantage. [Clarification Statement: Emphasis is on questions that seek evidence for arguments of how social interactions and group behaviors benefit organisms' abilities to survive and reproduce (e.g., gather food, flock, school, herd, hunt, migrate, raise young, protect themselves from weather, predators, natural hazards).] [Assessment Boundary: Assessments should provide evidence of students' abilities to recognize patterns that provide evidence of cause and effect relationships between behavior and survival advantage. These patterns may include similar behavior in multiple species that inhabit very different ecosystems (e.g., forest, ocean, desert, wetlands).]

MS-LS2-i. Ask questions to clarify the scientific, economic, political, and social justifications used in making decisions about maintaining biodiversity in ecosystems.* [Clarification Statement: Emphasis is on questions that differentiate scientific from other kinds of arguments and take into consideration that not all decisions are made by science alone.] [Assessment Boundary: The assessment should provide evidence that students are able to identify which aspects of an argument are based on scientific evidence and which aspects are based on social and economic arguments. Students should be able to relate the different arguments to the resulting stability of the ecosystem.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable models that support explanations of phenomena or solutions to problems.
- Ask questions that arise from careful observation of phenomena, models, or unexpected results. (MS-LS2-h),(MS-LS2-i)

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.
- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-LS2-a),(MS-LS4-i)
- Modify models based on their limitations to increase detail or clarity, or to explore what will happen if a component is changed. (MS-LS4-i)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Construct explanations for either qualitative or quantitative relationships between variables. (MS-LS2-d)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems
- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. 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. (MS-LS2-a)
- 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. (MS-LS2-d)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- 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. (MS-LS4-i),(MS-LS2-i)

LS2.D: Social Interactions and Group Behavior
- Groups may form because of genetic relatedness, physical proximity, or other recognition mechanisms (which may be species-specific). They engage in a variety of signaling behaviors to maintain the group's integrity or to warn of threats. Groups often dissolve if they no longer function to meet individuals' needs, if dominant members lose their place, or if other key members are removed from the group through death, predation, or exclusion by other members. (MS-LS2-h)

LS4.D: Biodiversity and Humans
- Biodiversity is the wide range of existing life forms that have adapted to the variety of conditions on Earth from terrestrial to marine ecosystems. Biodiversity includes genetic variation within a species, in addition to species variation in different habitats and ecosystem types (e.g., forests, grasslands, wetlands). (MS-LS4-i)
- 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. (MS-

Crosscutting Concepts

Patterns
- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. (MS-LS2-d)
- Patterns can be used to identify cause and effect relationships. (MS-LS2-h)

Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS2-a)
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS2-a)

Systems and System Models
- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. (MS-LS4-i),(MS-LS4-j)

Stability and Change
- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. (MS-LS2-i)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World
- The use of technologies are driven by people's 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-LS4-i),(MS-LS4-j),(MS-LS2-i)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

MS.Interdependent Relationships in Ecosystems

▪ Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (MS-LS4-j)	LS4-j) **ETS1.A: Defining and Delimiting an Engineering Problem** ▪ 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. (MS-LS4-j) ▪ Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (MS-LS4-i), (MS-LS4-j), (MS-LS2-i) **ETS1.B: Developing Possible Solutions** ▪ There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (MS-LS4-i), (MS-LS4-j), (MS-LS2-i)	--- ***Connections to Nature of Science*** **Science Addresses Questions About the Natural and Material World** ▪ Science limits its explanations to systems that lend themselves to observation and empirical evidence. (MS-LS4-j) ▪ Scientific knowledge can describes consequence of actions but does not make the decisions that society takes. (MS-LS2-i)

Connections to other topics in this grade-level: will be added in future versions.

Articulation across grade-levels: will be added in future versions.

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. *(MS-LS2-D),(MS-LS4-j)*
RST.6-8.7	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-j)
RST.6-8.8	Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. *(MS-LS4-j),(MS-LS2-h)*
RI.7.8	Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims. *(MS-LS4-j),(MS-LS2-h)*
WHST.6-8.1	Write arguments focused on discipline-specific content. *(MS-LS4-j),(MS-LS2-h),(MS-LS2-i)*
WHST.6-8.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(MS-LS2-d)*
WHST.6-8.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. *(MS-LS4-j),(MS-LS2-h),(MS-LS2-i)*
WHST.6-8.7	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-LS4-i)*, (MS-LS4-j), (MS-LS2-h), (MS-LS2-i)
SL.8.1	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-j)*
SL.6.3	Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not. *(MS-LS4-j)*
SL.7.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation. *(MS-LS4-j),(MS-LS2-h),(MS-LS2-i)*

Mathematics –

MP.4	Model with mathematics. *(MS-LS2-a)*
5.OA	Analyze patterns and relationships. (MS-LS2-a)
7.SP.3	Draw informal comparative inferences about two populations. (MS-LS2-a)
8.F	Use functions to model relationships between quantities. (MS-LS2-a)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

MS.Natural Selection and Adaptations

MS.Natural Selection and Adaptations

Students who demonstrate understanding can:

MS-LS4-a. Analyze data from the fossil record to describe evidence of the history of life on Earth. [Clarification Statement: Emphasis is on analyzing data from the fossil record to make warranted inferences about the connections between when an organism lived on Earth and the general nature of the climate or other environmental conditions that existed when the organism lived (e.g., fossils of salt water organisms in an area without an ocean indicates that an ocean once existed in this area, fossils of tropical plants in a desert area indicate the area once had a tropical climate, fossils of marine organisms found on the Colorado plateau indicate the area was once an ocean. Species now extinct but similar to organisms living today provide evidence for the evolution of life on Earth).] [Assessment Boundary: The assessment should measure students' abilities to create inferences about the history of life on Earth using given data.]

MS-LS4-c. Construct explanations for the anatomical similarities and differences between fossils of once living organisms and organisms living today and relate this to the assumption that events in natural systems occur in consistent patterns.* [Clarification Statement: Emphasis is on constructing explanations for the relationship of once living organisms to species living today based on the patterns of similarities or differences (e.g., dinosaurs are more closely related to lizards than to fish, homologous skeletal structures in mammals, horse evolution series from Eocene to present day horses). Students use these comparisons as evidence to support explanations and determine the strength of the evidence to support their assertions. Students base explanations on evidence and the assumption that natural laws operate today as they did in the past.]

MS-LS4-b. Construct explanations for why most individual organisms, as well as some entire species of organisms, that lived in the past were never fossilized. [Clarification Statement: Emphasis is on explanations that some organisms have only soft parts that do not fossilize under normal conditions, many organisms are eaten after they die. Additionally, some organisms die in places where decomposers and/or chemical processes consume the remains.] [Assessment Boundary: The assessments should provide evidence that students are able to use evidence to construct plausible explanations. The process of fossilization is not treated in any detail in life sciences, but is addressed in Earth sciences.]

MS-LS4-d. Analyze graphical displays 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 comparing patterns that appear as gross similarities and differences to provide evidence of general relationships among organisms that are more or less related.] [Assessment Boundary: These comparisons are limited to general characteristics of early embryological development of related species.]

MS-LS4-e. Construct explanations for how genetic variations of traits in a population increase some individual's probability of surviving and reproducing in a specific environment, which tends to increase these traits and suppress other traits in the population. [Clarification Statement: Emphasis is on using simple probability statements to communicate explanations for how variation of traits among organisms provides increased options for a population to survive and reproduce.] [Assessment Boundary: The assessment should provide evidence of students' abilities to explain why some traits are suppressed and other traits become more prevalent for those individuals better at finding food, shelter, or avoiding predators.]

MS-LS4-f. Use mathematical models to support the explanation of how natural selection over many generations results in changes within species in response to environmental conditions that tend to increase or decrease specific traits in a population. [Clarification Statement: Emphasis is on using mathematical models to explain trends based on data for changes in populations over time.] [Assessment Boundary: The assessment should provide evidence of students' abilities to explain trends in data for the number of individuals with specific traits changing over time.]

MS-LS4-h. Gather, read, and communicate information about how two populations of the same species in different environments have evolved to become separate species. [Clarification Statement: Emphasis is on students providing evidence that supports the mechanism by which the two populations of the same species in different environments have evolved separately and become separate species.] [Assessment Boundary: The assessment should provide evidence of students' abilities to determine the scientific evidence that supports the explanations for speciation.]

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

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.
- Develop models to describe unobservable mechanisms. (MS-LS4-f)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Construct, analyze, and interpret graphical displays of data to identify linear and nonlinear relationships. (MS-LS4-d)
- Analyze and interpret data in order to determine similarities and differences in findings. (MS-LS4-a)
- Distinguish between causal and correlational relationships. (MS-LS4-a)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.
- Apply concepts of ratio, rate, percent, basic operations, and simple algebra to scientific and engineering questions and problems. (MS-LS4-f)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity
- Fossils are mineral replacements, preserved remains, or traces of organisms that lived in the past. Thousands of layers of sedimentary rock not only provide evidence of the history of the Earth itself but also of changes in organisms whose fossil remains have been found in those layers. (MS-LS4-a)
- 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. Because of the conditions necessary for their preservation, not all types of organisms that existed in the past have left fossils that can be retrieved. (MS-LS4-b)
- 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-c)
- Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. (MS-LS4-d)

LS4.B: Natural Selection
- Genetic variations among individuals in a population give some individuals an advantage in surviving and reproducing in their environment. This is known as natural selection. It leads to the predominance of certain traits in a population, and the suppression of others. (MS-LS4-e),(MS-LS4-f)

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. (MS-LS4-f),(MS-LS4-h)
- Traits that support successful survival and reproduction in the

Crosscutting Concepts

Patterns
- Patterns can be used to identify cause and effect relationships. (MS-LS4-c)
- Graphs and charts can be used to identify patterns in data. (MS-LS4-a),(MS-LS4-d)

Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS4-b),(MS-LS4-e),(MS-LS4-f)

Stability and Change
- Small changes in one part of a system might cause large changes in another part. (MS-LS4-h)

Connections to Nature of Science

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-c)

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knowledge, principles, and theories. ▪ Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (MS-LS4-b), (MS-LS4-e) ▪ Base explanations on evidence obtained from sources (including their own experiments) and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (MS-LS4-c) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods. ▪ Gather, read, and communicate information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used. (MS-LS4-h) --- ***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-a)	new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. (MS-LS4-f) ▪ In separated populations with different conditions, the changes can be large enough that the populations, provided they remain separated (a process called reproductive isolation), evolve to be separate species. (MS-LS4-h)	

Connections to other topics in this grade-level: *will be added in future versions.*

Articulation across grade-levels: will be added in future versions.

Common Core State Standards Connections:

ELA /Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. *(MS-LS4-h)*
RST.6-8.2	Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-LS4-h)
RST.6-8.7	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-d),(MS-LS4-h)*
WHST.6-8.2	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-b)*
WHST.6-8.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. *(MS-LS4-b)*
WHST.6-8.8	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 while avoiding plagiarism and providing basic bibliographic information for sources. (MS-LS4-h)
WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research. (MS-LS4-h)
SL.8.1	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-b)*
SL.6.4	Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation. *(MS-LS4-e)*
SL.7.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. *(MS-LS4-f)*

Mathematics –

MP.2	Reason abstractly and quantitatively. (MS-LS4-a)
MP.6	Attend to precision. *(MS-LS4-d)*
MP.4	Model with mathematics. (MS-LS4-f)
5.OA	Analyze patterns and relationships. (MS-LS4-f),*(MS-LS4-d)*
6.EE	Represent and analyze quantitative relationships between dependent and independent variable. *(MS-LS4-f)*
8.EE	Understand the connections between proportional relationships, lines and linear equations. (MS-LS4-d)

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MS.Space Systems

MS.Space Systems

Students who demonstrate understanding can:

MS-ESS1-a. Use models of the Earth-sun-moon system to support explanations and predict the cyclic pattern of tides, eclipses, and observable constellations. [Clarification Statement: Earth's rotation relative to the positions of the moon and sun describes the occurrence of tides; the revolution of Earth around the sun explains the annual cycle of the apparent movement of the constellations in the night sky; the moon's revolution around Earth explains the cycle of spring/neap tides and the occurrence of eclipses; the moon's elliptical orbit explains the occurrence of total and annular eclipses.]

MS-ESS1-b. Use models of the Earth-sun system to support the explanation that the seasons are a result of Earth's tilt and are caused by the differential intensity and duration of sunlight on different regions of Earth over a year.

MS-ESS1-c. Construct and use scale models of the solar system to support the explanation of the motions of the planets as observed from Earth. [Clarification Statement: Models should include physical models (e.g., distance along a football field, visualization of elliptical orbits) or conceptual models (e.g., proportions relative to their school or state; the role of gravity in causing orbital motions).] [Assessment Boundary: Kepler's Laws of orbital motion are not assessed.]

MS-ESS1-d. Apply scientific knowledge to support explanations of how technologies developed for manned and unmanned space exploration provide information about the surfaces of planets, moons, and other solar system bodies.* [Clarification Statement: For example: The space probe Magellan was designed to use radar to map the topography of Venus, which was obscured by Venus' thick atmosphere; the space probe Galileo was designed to study the atmosphere of Jupiter and the geology of the Galilean satellites; the Mars exploration rovers Spirit, Opportunity, and Curiosity were designed to explore the Martian surface and subsurface for traces of prebiotic and biological activity. In each case, the limits of earlier technologies were overcome by modifying old designs or undertaking entirely new approaches.]

MS-ESS1-e. Communicate technical information about how instruments and other technologies have led to discoveries about the location of our solar system within the Milky Way galaxy, the expansion and scale of the universe, and the scientific theories that explain these observations.* [Clarification Statement: As examples, the first large optical telescopes made it possible to determine the position of our own solar system within the Milky Way and to identify other galaxies; radio telescopes detect the cosmic microwave background, which is interpreted to be the remnant heat left over from the Big Bang; the Hubble Space telescope looks deep into the universe and has detected galaxies in all stages of evolution; the Kepler Telescope produces observations of extrasolar planets in our galaxy.] [Assessment Boundary: Conceptual understanding that theories for explaining the origin and expansion of the universe are the result of scientists explaining the universe based on observations are included in the assessment; however, evidence such as the Doppler shift of starlight to construct explanations in support of the Big Bang theory and details of the electromagnetic spectrum are not assessed.]

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

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-ESS1-a),(MS-ESS1-b),(MS-ESS1-c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific knowledge and evidence to explain real-world phenomena, examples, or events. (MS-ESS1-d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.

- Communicate scientific information and/or technical information (e.g. about a proposed object, tool, process, system) in different formats (e.g., verbally, graphically, textually, and mathematically). (MS-ESS1-e)

Connections to Nature of Science

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

- Theories are explanations for observable phenomena. (MS-ESS1-e)
- Science theories are based on a body of evidence developed over time. (MS-ESS1-e)

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-a),(MS-ESS1-b)
- The universe began with a period of extreme and rapid expansion known as the Big Bang. (MS-ESS1-e)
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (MS-ESS1-c),(MS-ESS1-e)

ESS1.B: Earth and the Solar System

- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-c),(MS-ESS1-d)
- This model of the solar system can explain tides, eclipses of the sun and the moon, and the motion of the planets in the sky relative to the stars. (MS-ESS1-a),(MS-ESS1-c)
- Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. (MS-ESS1-b)

PS2.C: Stability and Instability in Physical Systems

- A system can be changing but have a stable repeating cycle of changes; such observed regular patterns allow predictions about the system's future (e.g., Earth orbiting the sun). (MS-ESS1-a),(MS-ESS1-b)

ETS1.A: Defining and Delimiting an Engineering Problem

- Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (MS-ESS1-d)

ETS1.C: Optimizing the Design Solution

- 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-ESS1-d),(MS-ESS1-e)

Crosscutting Concepts

Patterns

- Patterns can be used to identify cause and effect relationships. (MS-ESS1-a)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-ESS1-c),(MS-ESS1-e)

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (MS-ESS1-b)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems. Science and technology drive each other forward. (MS-ESS1-d),(MS-ESS1-e)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections: [Note: these connections will be made available soon.]
ELA/Literacy –
Mathematics –

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

MS.History of Earth

MS.History of Earth

Students who demonstrate understanding can:

MS-ESS1-g. Apply scientific reasoning using geologic evidence to determine the relative ages of a sequence of events that have occurred in Earth's past. [Clarification Statement: Evidence can be field evidence or simple representations (e.g., model of geologic cross-sections); "events" may include sedimentary layering, fossilization, folding, faulting, igneous intrusion, and/or erosion. These kinds of events will continue to happen in the future as they have in the past.]

MS-ESS1-f. Construct scale models of the geologic time scale to depict the relative timing of major events in Earth's history. [Clarification Statement: Models may be temporal (e.g., Earth's history scaled to a day or year) or spatial (e.g., scaled to a football field) and should show that the time between identified events is larger for Earth's early history. Major events could include the formation of mountain chains and ocean basins, evolution and extinction of particular living organisms, volcanic eruptions, periods of massive glaciation, and the development of watersheds and rivers through glaciation and water erosion. The events in Earth's history happened in the past continue today.] [Assessment Boundary: Memorization of specific periods or epochs of the geologic timescale is not assessed.]

MS-ESS2-d. Construct explanations from evidence for how different geoscience processes, over widely varying scales of space and time, have shaped Earth's history. [Clarification Statement: Mountain building can occur through large-scale plate tectonic processes while the chemical weathering of a mountain occurs at molecular scales; mountain building can take many millions of years, but events like large meteoroid impacts are nearly instantaneous. Many Earth-system processes normally behave gradually but are punctuated by catastrophic events (e.g., meteoroid impacts, earthquakes, volcanoes, stream floods, severe weather events). These processes will continue in the future as they have in the past. It is appropriate to use regional geographical features familiar to students from diverse backgrounds. Evidence can take the form of models or representations. Events in Earth's history continue to occur today as they did in the past.]

MS-ESS2-o. Use arguments supported by evidence from the rock and fossil records to explain how past changes in Earth's conditions have caused major extinctions of some life forms and allowed others to flourish. [Clarification Statement: The rapid climate change 245 million years ago correlates with the extinction of most existing species (including trilobites) but subsequent rise of new species (including dinosaurs.) The large meteoroid impact and extensive volcanism 65 million years ago correlate with a massive extinction of certain life forms (including dinosaurs) and subsequent proliferation of others (including mammals).]

MS-ESS2-p. Ask questions from evidence found in the geologic record to determine relationships between the evolution and proliferation of living things and changes in the geosphere, atmosphere, and hydrosphere over geologic time. [Clarification Statement: The geologic record includes both rock and fossil evidence. For example, the first occurrence of oxidized iron, found in 2.5 billion-year-old banded iron formations, is evidence for the early presence of oxygen in Earth's systems, most likely generated by the proliferation of photosynthesizing cyanobacteria.] [Assessment Boundary: Chemical reactions associated with the oxygen and carbon cycles are not assessed.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable models that support explanations of phenomena or solutions to problems.
- Ask questions to determine relationships between independent and dependent variables. (MS-ESS2-p)

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.
- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-ESS1-f),(MS-ESS2-p)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (MS-ESS1-g)
- Base explanations on evidence obtained from sources (including their own experiments) and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (MS-ESS2-d)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (MS-ESS2-o)

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth
- The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Major historical events include the formation of mountain chains and ocean basins, evolution and extinction of particular living organisms, volcanic eruptions, periods of massive glaciation, and the development of watersheds and rivers through glaciation and water erosion. (MS-ESS1-f),(MS-ESS2-o)
- Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (MS-ESS1-g),(MS-ESS2-o)

ESS2.A: Earth's Materials and Systems
- 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. (MS-ESS2-d)

ESS2.E: Biogeology
- Evolution is shaped by Earth's varying geologic conditions. Sudden changes in conditions (e.g., meteor impacts, major volcanic eruptions) have caused mass extinctions, but these changes, as well as more gradual ones, have ultimately allowed other life forms to flourish. (MS-ESS2-o)
- The evolution and proliferation of living things over geologic time have in turn changed the rates of weathering and erosion of land surfaces, altered the composition of Earth's soils and atmosphere, and affected the distribution of water in the hydrosphere. (MS-ESS2-p)

Crosscutting Concepts

Cause and Effect
- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. (MS-ESS2-p)

Scale, Proportion, and Quantity
- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-ESS1-g),(MS-ESS1-f)

Stability and Change
- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale. (MS-ESS2-d)
- Stability might be disturbed either by sudden events or gradual changes that accumulate over time. (MS-ESS2-o)

Connections to Nature of Science

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-ESS1-g),(MS-ESS1-f),(MS-ESS2-d)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections: [Note: these connections will be made available soon.]
ELA/Literacy –

Mathematics –

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MS.Earth's Interior Systems

MS.Earth's Interior Systems

Students who demonstrate understanding can:

MS-ESS3-f. Analyze and interpret data sets that indicate the location and frequency of earthquake, volcanic eruption, and tsunami hazards in a region and identify patterns that allow for forecasts of the likelihood and locations of future events.* [Clarification Statement: Data sets could be maps of the sizes and locations of earthquakes, animations of ocean tsunami propagation from earthquakes in different regions, or historical records of the timing and explosivity of past volcanic eruptions.]

MS-ESS2-e. Develop and use models of past plate motions to support explanations of existing patterns in the fossil record, rock record, continental shapes, and seafloor structures. [Clarification Statement: The evidence for past motions of tectonic plates is based on similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures such as ridges, fracture zones, and trenches.] [Assessment Boundary: Understanding of paleomagnetic anomalies in oceanic and continental crust is not assessed.]

MS-ESS2-f. Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, and conclusions that appear in scientific texts about the way new evidence for geologic activity at plate boundaries and the movements of Earth's surface has led to continual refinements of the theory of plate tectonics. [Clarification Statement: Geologic activity at plate boundaries includes volcanoes and the folding and faulting of rocks; plate motion evidence comes from satellites (such as GPS) and seismic imaging of the earth.]

MS-ESS2-a. Use plate tectonic models to support the explanation that, due to convection, matter cycles between Earth's surface and deep mantle. [Clarification Statement: Patterns of mantle convection and its surface expression (plate tectonics) result in the destruction of sea floor rock at subduction zones and the formation of ocean trenches. Earth materials come to the surface via volcanism at continental and oceanic rift zones, above subduction zones, and at intraplate volcanoes, some of which are associated with rising mantle plumes that appear to be largely independent of plate tectonics. Explanations should account for the formation of mid-ocean ridges and features at subduction zones such as ocean trenches.] [Assessment Boundary: Details of the various processes and forces that drive mantle convection are not assessed.]

MS-ESS2-g. Collect data and generate evidence to answer scientific questions about the chemical and physical processes that form rocks and minerals and cycle Earth materials. [Clarification Statement: Investigations can use various materials to simulate the processes of melting, crystallization, weathering, deformation, and sedimentation. These processes act together to cycle and recycle Earth materials.]

MS-ESS3-a. Construct explanations based on evidence from multiple sources for how the uneven distribution of Earth's mineral and energy resources, which are limited and typically non-renewable, is a result of past and current geologic processes often associated with plate tectonics.* [Clarification Statement: For example, the global distribution of coal is a result of the burial and lithification of ancient swamp matter; the global distribution of petroleum is the result of the burial of organic marine sediments and subsequent development of petroleum traps; and the global distribution of many precious metals (e.g., gold, copper) correlates with past volcanic and hydrothermal activity associated with subduction zones.]

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Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-ESS2-e),(MS-ESS2-a)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (MS-ESS2-g)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Use graphical displays (e.g., maps) of large data sets to identify temporal and spatial relationships. (MS-ESS3-f)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Base explanations on evidence obtained from sources (including their own experiments) and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (MS-ESS3-a)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.

- Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, conclusions that appear in

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth

- *Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches.* (*HS.ESS1.C GBE*) (MS-ESS2-e),(MS-ESS2-f),(MS-ESS2-a)

ESS2.A: Earth Materials and 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 of produces chemical and physical changes in Earth's materials and living organisms. (*Interior processes are addressed here. Surface processes are addressed in MS.ESS-ESS.*) (MS-ESS2-a)
- *The top part of the mantle, along with the crust, forms structures known as tectonic plates.* (*HS.ESS2.A GBE*) (MS-ESS2-e),(MS-ESS2-f),(MS-ESS2-a)
- *Solid rocks can be formed by the cooling of molten rock, the accumulation and consolidation of sediments, or the alteration of older rocks by heat, pressure, and fluids.* (*NRC Framework, p. 180*) (MS-ESS2-g)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- 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. (MS-ESS2-e)

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. (*Interior resources are addressed here. Surface resources are addressed in MS.ESS-ESS.*) (MS-ESS3-a)

ESS3.B: Natural Hazards

- Some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions. Others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. However, 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. (*Interior hazards are addressed here. Surface hazards are addressed in MS.ESS-ESP.*) (MS-ESS3-f)

Crosscutting Concepts

Patterns

- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. (MS-ESS2-e),(MS-ESS2-f)

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS3-f)

Energy and Matter

- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (MS-ESS2-a)

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and *processes* at different scales, including the atomic scale. (MS-ESS2-g)

Connections to Engineering, Technology, and Applications of Science

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

- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (MS-

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scientific and technical texts in light of competing information or accounts; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-ESS2-f) --- ***Connections to Nature of Science*** **Scientific Knowledge is Open to Revision in Light of New Evidence** ▪ Scientific explanations are subject to revision and improvement in light of new evidence. (MS-ESS2-f) **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ▪ Theories are explanations for observable phenomena. (MS-ESS2-f) ▪ Science theories are based on a body of evidence developed over time. (MS-ESS2-f) ▪ The term "theory," as used in science is very different from the common use outside of science. (MS-ESS2-f)	**PS4.A: Wave Properties** ▪ Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (MS-ESS3-f) **ETS1.A: Defining and Delimiting an Engineering Problem** ▪ Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (MS-ESS3-f)	ESS3-a)

Connections to other DCIs in this grade-level: will be added in future version.
Articulation to DCIs across grade-levels: will be added in future version.
Common Core State Standards Connections: [Note: these connections will be made available soon.]
ELA/Literacy –
Mathematics –

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MS.Earth's Surface Systems

MS.Earth's Surface Systems

Students who demonstrate understanding can:

MS-ESS2-b. Develop models to describe mechanisms for the cycling of water through Earth's systems as water changes phase and moves in response to energy from the sun and the force of gravity. [Clarification Statement: Water changes its state as it moves through the multiple pathways of the hydrologic cycle, through transpiration, evaporation, crystallization, and condensation; these processes are largely driven by energy from the sun. Models can be conceptual or physical.] [Assessment Boundary: The latent heats of vaporization and fusion are not assessed.]

MS-ESS2-k. Design and conduct investigations to support explanations of how changes in temperature and salinity cause changes in ocean water density and as a result, affect the formation and movement of interconnected ocean currents. [Clarification Statement: Physical investigations with water could serve as the basis for explanations about the movements of ocean currents.]

MS-ESS2-c. Formulate questions that can be investigated and frame hypotheses about how the characteristics and movement of water affect the weathering, transportation, and deposition of surface and sub-surface materials. [Clarification Statement: Physical investigations with water and a variety of solid materials provide the evidence for formulating questions concerning links between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of investigations are of stream transportation and deposition using a stream table; chemical weathering by testing the solubility of certain minerals; erosion using soil moisture content; or frost wedging by examining the expansion of water as it freezes.]

MS-ESS2-l. Generate and communicate ideas about how movements of water, ice, and wind shape landscapes and create geologic formations, above and below ground, through the mechanisms of weathering, transportation, and deposition of Earth materials. [Clarification Statement: Though internal processes are largely responsible for creating land, the movements of water, ice, and wind are largely responsible for its appearance, including caves; many minerals are made by surface weathering and depositional processes. Models may include maps or diagrams, and sources of information may include GIS databases, NOAA reports and databases, and State Natural Resources websites or reports.]

MS-ESS3-b. Construct explanations for the formation of soil types and other natural resources that result from the weathering and/or deposition of rocks and for how knowledge of these processes has led to changes in conservation practices. [Clarification Statement: Surface processes involving physical and chemical interactions among rocks, sediments, water, air, and living organisms lead to the formation of many rock and mineral resources such as soils, salts, sand and gravel, borates, and placer deposits of gold and other heavy metals. The development of soil is a very slow process, causing this important natural resource to be non-renewable over the short term. Changes in our knowledge of the process and timeline for soil formation and resource depletion have changed the conservation practices over time.]

MS-ESS3-g. Apply scientific knowledge to evaluate and revise engineered solutions to mitigate the effects of natural hazards that result from surface geologic and hydrologic processes. [Clarification Statement: Examples of surface-system natural hazards include avalanches, landslides, coastal erosion, and severe weather events (hurricanes, tornadoes, floods, droughts, forest fires). Engineered solutions can be both large-scale (satellite systems to monitor hurricanes) or regional (building basements in tornado-prone regions).] [Assessment Boundary: Efforts to predict or forecast severe weather events are not assessed here but appear in MS.ESS-WC.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable models that support explanations of phenomena or solutions to problems.

- Formulate a question that can be investigated within the scope of the classroom, school laboratory, or field with available resources and, when appropriate, frame a hypothesis (a possible explanation that predicts a particular and stable outcome) based on a model or theory. (MS-ESS2-c)

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Develop models to describe unobservable mechanisms. (MS-ESS2-b)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Design 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 much data are needed to support their claim. (MS-ESS2-k),(MS-ESS2-c)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (MS-ESS2-c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions

Disciplinary Core Ideas

ESS2.A: Earth Materials and 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. (MS-ESS2-b),(MS-ESS2-c)

ESS2.C: The Roles of Water in Earth's Surface Processes

- 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. (MS-ESS2-b)
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. (MS-ESS2-k)
- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations. (MS-ESS2-l)

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. (*Surface resources are addressed here. Interior resources are addressed in MS.ESS-EIS.*) (MS-ESS3-b)

ESS3.B: Natural Hazards

- Some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions. Others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. However, 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. (*Surface hazards are addressed here. Interior hazards are addressed in MS.ESS-EIS.*) (MS-ESS3-g)

ETS1.B: Developing Possible Solutions

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS3-b)
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-ESS3-b)

Systems and System Models

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. (MS-ESS2-l)
- Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems. (MS-ESS2-l)

Energy and Matter

- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (MS-ESS2-b),(MS-ESS2-k),(MS-ESS2-c)

Connections to Engineering, Technology, and Applications of Science

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

- The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ESS3-g)

Connections to Nature of Science

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supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories. ▪ Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (MS-ESS3-b) ▪ Apply scientific knowledge and evidence to explain real-world phenomena, examples or events. (MS-ESS3-g) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods. ▪ Gather, read, and communicate information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used. (MS-ESS2-l)	▪ There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (MS-ESS3-g)	**Science is a Way of Knowing** ▪ Science knowledge is cumulative and many people, from many generations, and nations have contributed to science knowledge. (MS-ESS3-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections: [Note: these connections will be made available soon.]
ELA/Literacy –

Mathematics –

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MS.Weather and Climate

MS.Weather and Climate

Students who demonstrate understanding can:

MS-ESS2-m. Apply concepts of statistics to analyze weather data and identify the variability that requires weather forecasts to be issued in terms of probabilities. [Clarification Statement: Analyzing measurements (e.g., value, mean, median, mode, range) of weather data (e.g., temperature, pressure, humidity, precipitation, wind speed) and comparing them to weather forecasts (e.g., a projected high of 35°C with 40% chance of rain) demonstrate the nature of the unpredictability of weather; data can be for local areas or for other regions, and be on a daily basis or obtained from regional NOAA National Weather Service online databases.] [Assessment Boundary: Computing weather forecasts is not assessed.]

MS-ESS2-n. Use models of Earth's atmosphere and surface to support the explanation of the greenhouse effect. [Clarification Statement: Model explanations, physical or conceptual, reveal various ways that heat energy moves through and is stored within Earth's systems.] [Assessment Boundary: The rates of energy absorption by different reservoirs and their effect on the radiation balance of the system are not assessed. A complete understanding of the electromagnetic spectrum is not assessed.]

MS-ESS2-h. Construct and use models to support the explanation of how the unequal heating of Earth's surface and Earth's rotation result in patterns of atmospheric and oceanic circulation that vary with latitude, altitude, and geographic land distribution. [Clarification Statement: Atmospheric circulation includes sunlight-driven latitudinal banding and resulting prevailing winds (trade winds, westerlies, and polar easterlies); ocean circulation includes deep ocean currents (North Atlantic Deep Water), surface currents (the Gulf Stream), and gyres (the North Pacific Gyre). Models can include diagrams, maps, globes, or digital representations.] [Assessment Boundary: The dynamics of the Coriolis effect are not assessed.]

MS-ESS2-i. Collect data and generate evidence to show how changes in weather conditions result from the motions and interactions of air masses. [Clarification Statement: Air masses flow from regions of high pressure to low pressure, causing weather (e.g., temperature, pressure, humidity, precipitation, wind) at a fixed location to change over time. Sudden changes in weather and precipitation can result when different air masses collide.] [Assessment Boundary: Memorizing the names of cloud types or the meanings of weather symbols that are used on weather maps and weather station reporting diagrams is not assessed.]

MS-ESS2-j. Construct explanations from models of oceanic and atmospheric circulation for the development of local and regional climates. [Clarification Statement: Global patterns of atmospheric circulation control the uneven distribution of precipitation, such as the polar deserts and band of deserts near 30° north and south. Regional temperatures are controlled by latitude, altitude, and unique patterns in ocean/atmosphere circulation (e.g., Gulf Stream, Pacific Equatorial Current), which can also change over time (e.g., El Niño events). Students should construct explanations for their local climate.] [Assessment Boundary: Names of climate regions and classifications (e.g., the Köeppen classification) are not assessed.]

MS-ESS3-h. Analyze maps or other graphical displays of data sets to assess the likelihood and possible location of future severe weather events.* [Clarification Statement: Students could examine data sets on the frequency, magnitude, and resulting damage from severe weather events (e.g., hurricanes, typhoons, floods, droughts) to determine the geographic regions most at risk from these hazards. Better technologies have lead to the development of more accurate maps and data collection instruments.] [Assessment Boundary: In working with weather maps, memorization of weather map symbols is not assessed. Graphical displays of large data sets should be grade-appropriate.]

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Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-ESS2-n),(MS-ESS2-h)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (MS-ESS2-i)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible. (MS-ESS2-m)
- Use graphical displays (e.g., maps) of large data sets to identify temporal and spatial relationships. (MS-ESS3-h)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Apply concepts of ratio, rate, percent, basic operations, and simple algebra to scientific and engineering questions and problems. (MS-ESS2-m)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct explanations from models or representations. (MS-

Disciplinary Core Ideas

ESS2.C: The Roles of Water in Earth's Surface Processes

- 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. (MS-ESS2-h),(MS-ESS2-i),(MS-ESS2-j)

ESS2.D: 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. (*CS: Temperature patterns, together with Earth's rotation and the configuration of continents and oceans, control the large-scale patterns of atmospheric circulation. ESS2.D front matter, p. 186.)* (MS-ESS2-h),(MS-ESS2-i)
- Because these patterns are so complex, weather can only be predicted probabilistically. (MS-ESS2-m)
- 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. (MS-ESS2-h),(MS-ESS2-i),(MS-ESS2-j)
- Greenhouse gases in the atmosphere absorb and retain the energy radiated from land and ocean surfaces, thereby regulating Earth's average surface temperature and keeping it habitable. (MS-ESS2-n)

ESS3.B: Natural Hazards

- Some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that will allow for reliable predictions. Others, such as earthquakes, occur suddenly and with no notice, and thus they are not yet predictable. However, 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-h)

ETS1.A: Defining and Delimiting 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. (MS-ESS3-h)

Crosscutting Concepts

Patterns

- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. (MS-ESS3-h)

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-ESS2-m),(MS-ESS2-i)

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. (MS-ESS2-j)

Energy and Matter

- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (MS-ESS2-h)
- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-ESS2-n)
- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-ESS2-n)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems. Science and technology drive each other forward. (MS-ESS3-h)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

ESS2-i),(MS-ESS2-j) --- ***Connections to Nature of Science*** **Scientific Knowledge is Open to Revision in Light of New Evidence** ▪ Science findings are frequently revised and/or reinterpreted based on new evidence. (MS-ESS2-m)		

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections: [Note: these connections will be made available soon.]
ELA/Literacy –

Mathematics –

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

MS.Human Impacts

MS.Human Impacts

Students who demonstrate understanding can:

MS-ESS3-j. Ask questions to refine explanations for how different technologies are used to monitor Earth system changes, providing the basis of assessing human impacts.* [Clarification Statement: Examples of questions are, "How do we know the size of the ozone hole over Antarctica?" or "How do we measure the change over time of global temperatures?" Technological monitoring could include: (1) data from satellites for changes in vegetation, land use, surface water content, surface temperature, ice surface area, sea ice, ocean temperature and wave height, atmosphere chemistry and temperature, storm activity, and aerosol content; (2) ice and sediment cores for data on past temperatures and atmospheric composition; (3) data from land and ocean-based weather stations, from ocean buoys, or from river or lake monitoring stations for stream acidity, chemistry, and height; and, (4) data from seismic monitoring for glacier movements and impacts of waste-water injection.] [Assessment Boundary: An analysis of the causal correlations between human activities and changes to Earth's systems is not assessed.]

MS-ESS3-i. Use visual representations of system models to support explanations of how human activities significantly impact: (1) the geosphere, (2) the hydrosphere, (3) the atmosphere, and (4) the biosphere.* [Clarification Statement: System models and representations can include diagrams, charts, photographs, and maps that demonstrate how these systems have changed over time in response to human activities, examples of which include changes in land use and resource development (geosphere); water pollution and urbanization (hydrosphere); air pollution in the form of gases, aerosols, and particulates (atmosphere); transfer of invasive species to new environments (biosphere).]

MS-ESS3-k. Apply scientific knowledge to construct explanations from databases for how increases in human population and the consumption of natural resources impact Earth's systems. [Clarification Statement: Data could come from age-appropriate databases on human populations and rates of consumption of natural resources (water, mineral, and energy), and biosphere resources (such as from the USGS). Impacts 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 to Earth's 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-c. Construct and use oral and written arguments supported by empirical evidence to balance competing demands for various human uses of fresh water and biosphere resources.* [Clarification Statement: Arguments should consider a number of different needs for the same resources to arrive at optimal solutions. Factors to consider could include geographic availability, costs, benefits, sustainability, and environmental impacts of their uses. Resources include stream water, lake water, groundwater, glacier runoff, agricultural crops, land- and water-based organisms, building materials, biomass fuels, plant-based textiles, pharmaceutical stocks, and atmospheric oxygen. The consequences of how fresh water resources are used are described by science, but science does not make the decisions for the actions society takes.]

MS-ESS3-d. Read critically to evaluate competing ideas and present the findings regarding the use of technologies that rely on renewable and non-renewable energy resources.* [Clarification Statement: Reading sources could be scientific assessments such as the National Research Council's, "America's Energy Future" study and other NRC publications. Energy resources include renewable energy resources (e.g., hydroelectric, geothermal, biomass fuels), inexhaustible energy sources (e.g., sunlight, wind, tides, ocean waves), and non-renewable energy sources (e.g., coal, oil, natural gas, nuclear fission). Constraints on resource use include geographic availability, costs, benefits, safety, performance, sustainability, and environmental impacts.]

MS-ESS3-e. Design and communicate solutions that meet criteria and constraints for minimizing human impacts on environments and local landscapes by: (1) managing water resources, (2) reducing pollution, and (3) reducing the release of greenhouse gases.* [Clarification Statement: The design process could include examining an example of human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating a solution that could reduce that impact. Examples of human "impacts" include but are not limited to: (1) the withdrawal of stream water and groundwater, construction of dams and levees, and removal of wetlands; (2) air and water pollution, light pollution, noise pollution, landfill contamination, and plastics in the ocean; and, (3) carbon dioxide release from combustion and cement production, methane release from agriculture and the warming of permafrost and coastal regions, and nitrous oxide release.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable models that support explanations of phenomena or solutions to problems.

- Ask questions to clarify and refine a model, an explanation, or an engineering problem. (MS-ESS3-j)

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-ESS3-i)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (MS-ESS3-k)
- Apply scientific knowledge and evidence to explain real-world phenomena, examples, or events. (MS-ESS3-e)
- Apply scientific knowledge to design, construct, and test a design of an object, tool, process or system. (MS-ESS3-e)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–

Disciplinary Core Ideas

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-c),(MS-ESS3-d),(MS-ESS3-e)
- Renewable energy resources and the technologies to exploit them are being rapidly developed. (MS-ESS3-d)

ESS3.C: Human Impacts on Earth Systems

- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-i),(MS-ESS3-e)
- 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-j),(MS-ESS3-i),(MS-ESS3-k),(MS-ESS3-e)

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-e)

ETS1.A: Defining and Delimiting an Engineering Problem

- 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. (MS-ESS3-c),(MS-ESS3-d),(MS-ESS3-e)
- Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS3-e)

Systems and System Models

- Models can be used to represent systems and their interactions – such as inputs, processes, and outputs - and energy, matter, and information flows within systems. (MS-ESS3-i)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems. Science and technology drive each other forward. (MS-ESS3-j)

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

- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ESS3-i),(MS-ESS3-k),(MS-ESS3-c),(MS-ESS3-d)
- The uses of technologies and limitations on

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5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world. ▪ Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (MS-ESS3-c) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods. ▪ Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, conclusions that appear in scientific and technical texts in light of competing information or accounts; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-ESS3-d)	solutions. (MS-ESS3-c),(MS-ESS3-d),(MS-ESS3-e) **ETS1.B: Developing Possible Solutions** ▪ There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (MS-ESS3-c),(MS-ESS3-d),(MS-ESS3-e) ▪ It is important to be able to communicate and explain solutions to others. (MS-ESS3-i),(MS-ESS3-e) ▪ Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ESS3-c),(MS-ESS3-d),(MS-ESS3-e) ▪ Models of all kinds are important for testing solutions, and computers are a valuable tool for simulating systems. (MS-ESS3-i) **ETS1.C: Optimizing the Design Solution** ▪ Once a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful. (MS-ESS3-i),(MS-ESS3-e)	their use are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (MS-ESS3-c),(MS-ESS3-d),(MS-ESS3-e) --- ***Connections to Nature of Science*** **Science Addresses Questions About the Natural and Material World.** ▪ Science knowledge can describe consequences of actions but does not make the decisions that society takes. (MS-ESS3-k),(MS-ESS3-c)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections: [Note: these connections will be made available soon.]

ELA/Literacy –
Mathematics –

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MS.Engineering Design

MS.Engineering Design

[Note: All of these performance expectations can also be found in other standards.]

Students who demonstrate understanding can:

MS-PS2-f. **Define a practical problem that can be solved through the development of a simple system that requires the periodic application of a force initiated by a feedback mechanism to maintain a stable state.*** [Clarification Statement: Examples include a weather vane or a wind sock at an airport.]

MS-PS3-a. **Construct and interpret graphical displays to describe the relationships between the kinetic energy of an object and its mass, and between the kinetic energy of an object and its speed, in order to better define a real world problem.*** [Clarification Statement: Data are provided to students. Examples could include riding a bicycle, rolling a rock downhill, and getting hit by a hardball versus a tennis ball.] [Assessment Boundary: A focus on calculating kinetic energy from the equation is not intended.]

MS-PS3-c. **Design, construct, and test a device that either minimizes or maximizes thermal energy transfer by conduction, convection, and/or radiation.*** [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup. Care should be taken with devices that concentrate significant amounts of energy.] [Assessment Boundary: Quantitative measures of thermal energy transfer are not assessed.]

MS-LS4-j. **Use arguments supported by scientific evidence and social and economic rationale to evaluate plans for maintaining biodiversity and ecosystem services.*** [Clarification Statement: Emphasis is on determining the best evidence for an argument about biodiversity in light of economic and social considerations in real world situations. Students should be able to determine the evidence that is consistent with science and evidence based on economic and/or social considerations. Focus is on how humans benefit from health ecosystems (e.g., food, energy, medicines).] [Assessment Boundary: Consideration of ecosystem services for humans may include but is not limited to water purification and recycling.]

MS-ESS3-c. **Construct and use oral and written arguments supported by empirical evidence to balance competing demands for various human uses of fresh water and biosphere resources.*** [Clarification Statement: Arguments should consider a number of different needs for the same resources to arrive at optimal solutions. Factors to consider could include geographic availability, costs, benefits, sustainability, and environmental impacts of their uses. Resources include stream water, lake water, groundwater, glacier runoff, agricultural crops, land- and water-based organisms, building materials, biomass fuels, plant-based textiles, pharmaceutical stocks, and atmospheric oxygen. The consequences of how fresh water resources are used are described by science, but science does not make the decisions for the actions society takes.]

MS-ESS3-d. **Read critically to evaluate competing ideas and present the findings regarding the use of technologies that rely on renewable and non-renewable energy resources.*** [Clarification Statement: Reading sources could be scientific assessments such as the National Research Council's, "America's Energy Future" study and other NRC publications. Energy resources include renewable energy resources (e.g., hydroelectric, geothermal, biomass fuels), inexhaustible energy sources (e.g., sunlight, wind, tides, ocean waves), and non-renewable energy sources (e.g., coal, oil, natural gas, nuclear fission). Constraints on resource use include geographic availability, costs, benefits, safety, performance, sustainability, and environmental impacts.]

MS-ESS3-e. **Design and communicate solutions that meet criteria and constraints for minimizing human impacts on environments and local landscapes by: (1) managing water resources, (2) reducing pollution, and (3) reducing the release of greenhouse gases.*** [Clarification Statement: The design process could include examining an example of human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating a solution that could reduce that impact. Examples of human "impacts" include but are not limited to: (1) the withdrawal of stream water and groundwater, construction of dams and levees, and removal of wetlands; (2) air and water pollution, light pollution, noise pollution, landfill contamination, and plastics in the ocean; and, (3) carbon dioxide release from combustion and cement production, methane release from agriculture and the warming of permafrost and coastal regions, and nitrous oxide release.]

MS-ESS3-h. **Analyze maps or other graphical displays of data sets to assess the likelihood and possible location of future severe weather events.*** [Clarification Statement: Students could examine data sets on the frequency, magnitude, and resulting damage from severe weather events (e.g., hurricanes, typhoons, floods, droughts) to determine the geographic regions most at risk from these hazards. Better technologies have lead to the development of more accurate maps and data collection instruments.] [Assessment Boundary: In working with weather maps, memorization of weather map symbols is not assessed. Graphical displays of large data sets should be grade-appropriate.]

MS-PS1-b. **Design a solution that solves a practical problem by using characteristic chemical and physical properties of pure substances.*** [Clarification Statement: Real world problems could involve the need to test for water quality, or mineral content of ores. Properties of substances can include melting and boiling points, density, solubility, reactivity, reaction with oxygen, and phase at a given temperature.] [Assessment Boundary: Limited to simple common substances (e.g., sodium chloride, sugar, sodium bicarbonate, calcium chloride, water, methane, propane, hydrogen, oxygen, steam).]

MS-LS2-i. **Ask questions to clarify how patterns of social interactions and grouping behaviors contribute to a survival Ask questions to clarify the scientific, economic, political, and social justifications used in making decisions about maintaining biodiversity in ecosystems.*** [Clarification Statement: Emphasis is on questions that differentiate scientific from other kinds of arguments and take into consideration that not all decisions are made by science alone.] [Assessment Boundary: The assessment should provide evidence that students are able to identify which aspects of an argument are based on scientific evidence and which aspects are based on social and economic arguments. Students should be able to relate the different arguments to the resulting stability of the ecosystem.]

MS-LS4-i. **Use a model of managed ecosystems to evaluate and improve proposals to maintain ecosystem biodiversity.*** [Clarification Statement: Emphasis is on providing an explanation for how a more diverse population in an ecosystem adds to the stability of the ecosystem and how humans who engineer and manage ecosystems (e.g., wildlife refuges, national parks, agricultural range lands) need to take biodiversity into account.] [Assessment Boundary: The assessment should provide evidence that students can evaluate various plans and consider the role of biodiversity in the strengths and weaknesses of the plans.]

MS-ESS1-d. **Apply scientific knowledge to support explanations of how technologies developed for manned and unmanned space exploration provide information about the surfaces of planets, moons, and other solar system bodies.*** [Clarification Statement: For example: The space probe Magellan was designed to use radar to map the topography of Venus, which was obscured by Venus' thick atmosphere; the space probe Galileo was designed to study the atmosphere of Jupiter and the geology of the Galilean satellites; the Mars exploration rovers Spirit, Opportunity, and Curiosity were designed to explore the Martian surface and subsurface for traces of prebiotic and biological activity. In each case, the limits of earlier technologies were overcome by modifying old designs or undertaking entirely new approaches.]

MS-ESS3-f. **Analyze and interpret data sets that indicate the location and frequency of earthquake, volcanic eruption, and tsunami hazards in a region and identify patterns that allow for forecasts of the likelihood and locations of future events.*** [Clarification Statement: Data sets could be maps of the sizes and locations of earthquakes, animations of ocean tsunami propagation from earthquakes in different regions, or historical records of the timing and explosivity of past volcanic eruptions.]

MS-PS1-g. **Design, construct, and test a device that either releases or absorbs thermal energy by chemical processes.*** [Clarification Statement: Design solutions could involve chemical reactions such as dissolving ammonium chloride, or burning a food item and measuring the

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temperature of water heated from the reaction.] [Assessment Boundary: Criteria other than temperature and time are not intended in testing the device.]

MS-PS3-g. Modify the design of a machine to improve its efficiency by reducing energy transfer to the surrounding environment.* [Clarification Statement: Energy transfer can include the transfer of energy from motion to thermal energy due to friction. Solutions should focus on the use of advancements in technological and material science to reduce environmental impacts. Familiar machines could include vehicles, bicycles, and pulleys.]

MS-LS2-g. Make an oral or written argument from evidence to support or refute the merits and constraints of different plans to solve a real world problem to restore a disrupted ecosystem.* [Clarification Statement: Emphasis is on distinguishing between effective arguments for merits of competing plans to restore (e.g., remediation plan, reclamation plan, flood control, controlled burns) a disrupted ecosystem.] [Assessment Boundary: The assessment should provide evidence of students' abilities to use systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.]

MS-ESS3-g. Apply scientific knowledge to evaluate and revise engineered solutions to mitigate the effects of natural hazards that result from surface geologic and hydrologic processes.* [Clarification Statement: Examples of surface-system natural hazards include avalanches, landslides, coastal erosion, and severe weather events (hurricanes, tornadoes, floods, droughts, forest fires). Engineered solutions can be both large-scale (satellite systems to monitor hurricanes) or regional (building basements in tornado-prone regions).] [Assessment Boundary: Efforts to predict or forecast severe weather events are not assessed here but appear in MS.ESS-WC.]

MS-ESS3-i. Use visual representations of system models to support explanations of how human activities significantly impact: (1) the geosphere, (2) the hydrosphere, (3) the atmosphere, and (4) the biosphere.* [Clarification Statement: System models and representations can include diagrams, charts, photographs, and maps that demonstrate how these systems have changed over time in response to human activities, examples of which include changes in land use and resource development (geosphere); water pollution and urbanization (hydrosphere); air pollution in the form of gases, aerosols, and particulates (atmosphere); transfer of invasive species to new environments (biosphere).]

MS-PS2-a. Develop a graphical or physical model, based on Newton's Third Law, to test solutions to a practical problem by predicting the motion of two interacting objects.* [Clarification Statement: Examples of practical problems could include safety tests on cars that collide with other cars or stationery objects; or the impact of a meteor on a space vehicle.] [Assessment Boundary: Restricted to vertical or horizontal interactions in one dimension.]

MS-PS2-c. Ask questions about data to clarify the factors that affect the strength of electric and magnetic forces to improve the performance of an electromagnetic device.* [Clarification Statement: Devices could include electromagnets, electric motors, or generators. Empirical data can include measuring the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [Assessment Boundary: Assessment of Coulomb's Law is not intended.]

MS-ESS1-e. Communicate technical information about how instruments and other technologies have led to discoveries about the location of our solar system within the Milky Way galaxy, the expansion and scale of the universe, and the scientific theories that explain these observations.* [Clarification Statement: As examples, the first large optical telescopes made it possible to determine the position of our own solar system within the Milky Way and to identify other galaxies; radio telescopes detect the cosmic microwave background, which is interpreted to be the remnant heat left over from the Big Bang; the Hubble Space telescope looks deep into the universe and has detected galaxies in all stages of evolution; the Kepler Telescope produces observations of extrasolar planets in our galaxy.] [Assessment Boundary: Conceptual understanding that theories for explaining the origin and expansion of the universe are the result of scientists explaining the universe based on observations are included in the assessment; however, evidence such as the Doppler shift of starlight to construct explanations in support of the Big Bang theory and details of the electromagnetic spectrum are not assessed.]

MS-PS4-e. Use digital tools and mathematical concepts to compare two or more digital representations of information to determine which represents the optimal tradeoff between performance and cost for a given kind of communication device in a real world context.* [Clarification Statement: Transmitting information includes detecting, sensing, and interpreting a signal. Performance can be subjectively judged as clarity, sharpness of an image, or length of a text. Advances in digital technology influence the progress of science and science has influenced advances in digital technology.]

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

Asking Questions and Defining Problems

Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable models that support explanations of phenomena or solutions to problems.

- Ask questions that arise from careful observation of phenomena, models, or unexpected results. (MS-LS2-i)
- Ask questions to clarify and refine a model, an explanation, or an engineering problem. (MS-PS2-c)
- 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-PS2-f)

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-LS4-i),(MS-PS2-a),(MS-ESS3-i)
- Modify models based on their limitations to

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting an Engineering Problem

- 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. (MS-PS2-f),(MS-PS3-a),(MS-PS3-c),(MS-LS4-j),(MS-ESS3-h),(MS-ESS3-c),(MS-ESS3-d),(MS-ESS3-e)
- Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (MS-PS1-b),(MS-PS3-a),(MS-PS3-c),(MS-LS2-i),(MS-LS4-i),(MS-LS4-j),(MS-ESS1-d),(MS-ESS3-f),(MS-ESS3-c),(MS-ESS3-d),(MS-ESS3-e)

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-PS1-g),(MS-PS3-c),(MS-PS3-g)
- There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (MS-LS4-i), (MS-LS4-j),(MS-LS2-i),(MS-LS2-g),(MS-PS1-b),(MS-PS1-g),(MS-PS3-c),(MS-ESS3-g),(MS-ESS3-c),(MS-ESS3-d),(MS-ESS3-e)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-LS2-g), (MS-ESS3-c),(MS-ESS3-d),(MS-ESS3-e)
- It is important to be able to communicate and explain solutions to others. (MS-ESS3-i),(MS-ESS3-e)
- Models of all kinds are important for testing solutions, and computers are a valuable tool for simulating systems. (MS-PS2-a), (MS-ESS3-i)
- Simulations are useful for predicting what would happen if various parameters of the model were changed, as well as for making improvements to the model based on peer and leader (e.g., teacher) feedback. (MS-PS2-a)

ETS1.C: Optimizing the Design Solution

Crosscutting Concepts

Patterns

- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. (MS-ESS3-h)

Cause and Effect

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. (MS-PS2-c)
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-c),(MS-ESS3-f),(MS-ESS3-e)

Energy and Matter

- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-PS3-c),(MS-PS3-g)
- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS1-g), (MS-PS3-c),(MS-PS3-g)

Structure and Function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. (MS-PS1-b)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be

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increase detail or clarity, or to explore what will happen if a component is changed. (MS-LS4-i)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Construct, analyze, and interpret graphical displays of data to identify linear and nonlinear relationships. (MS-PS3-a)
- Use graphical displays (e.g., maps) of large data sets to identify temporal and spatial relationships. (MS-ESS3-f),(MS-ESS3-h)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use digital tools, mathematical concepts, and arguments to test and compare proposed solutions to an engineering design problem. (MS-PS4-e)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Undertake design projects, engaging in the design cycle, to construct and implement a solution that meets specific design criteria and constraints. (MS-PS1-b)
- Apply scientific knowledge to design, construct, and test a design of an object, tool, process or system. (MS-PS1-g),(MS-PS3-c),(MS-ESS3-e)
- Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing. (MS-PS3-g)
- Apply scientific knowledge and evidence to explain real-world phenomena, examples, or events. (MS-ESS1-d),(MS-ESS3-g),(MS-ESS3-e)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.

- Communicate scientific information and/or technical information (e.g. about a proposed object, tool, process, system) in different formats (e.g., verbally, graphically, textually, and mathematically). (MS-ESS1-e)
- Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, conclusions that appear in scientific and technical texts in light of competing information or accounts; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-ESS3-d)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (MS-LS4-j),(MS-ESS3-c)
- Make an oral or written argument that refutes the advertised performance of a device, process, or system, based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints. (MS-LS2-g)

- Comparing different designs could involve running them through the same kinds of tests and systematically recording the results to determine which design performs best. (MS-PS1-g),(MS-PS2-c)
- This 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-PS1-g),(MS-PS3-g),(MS-ESS1-d),(MS-ESS1-e)
- Once a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful. (MS-PS4-e),(MS-ESS3-i),(MS-ESS3-e)

observed at various scales using models to study systems that are too large or too small. (MS-LS2-g),(MS-ESS1-e)

- 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-a)
- Scientific relationships can be represented through the use of algebraic expressions and equations. (MS-PS3-a)

Systems and System Models

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. (MS-LS4-i),(MS-LS4-j)
- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. (MS-PS2-a),(MS-ESS3-i)
- Models are limited in that they only represent certain aspects of the system under study. (MS-PS2-a)

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. (MS-LS2-i)
- Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (MS-PS2-f)

Connections to Engineering, Technology, and Applications of Science

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

- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-PS1-b),(MS-ESS3-i),(MS-ESS3-c),(MS-ESS3-d)
- The use of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-PS2-a),(MS-PS2-f),(MS-LS4-i),(MS-LS4-j),(MS-LS2-i),(MS-PS1-b),(MS-ESS3-g) (MS-ESS3-c),(MS-ESS3-d),(MS-ESS3-e)
- Thus technology use varies from region to region and over time. (MS-LS4-i),(MS-LS4-j),(MS-LS2-i),(MS-PS1-b),(MS-ESS3-c),(MS-ESS3-d),(MS-ESS3-e)

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. Science and technology drive each other forward. (MS-ESS1-d),(MS-ESS1-e),(MS-ESS3-h)

Connections to Nature of Science

Science Addresses Questions About the Natural and Material World

- Science limits its explanations to systems that lend themselves to observation and empirical evidence. (MS-LS4-j)
- Scientific knowledge can describes consequence of actions but does not make the decisions that society takes. (MS-LS2-i), (MS-ESS3-c)

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		▪ Advances in technology influence the progress of science and science has influenced advances in technology. (MS-PS1-b) **Science is a Human Endeavor** ▪ Advances in technology influence the progress of science and science has influenced advances in technology. (MS-PS4-e)

Connections to other topics in this grade-level: will be added in future versions.

Articulation across grade-levels: will be added in future versions.

Common Core State Standards Connections: [Note: Earth and Space Science connections will be made available soon.]

ELA/Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. *(MS-LS4-j)*
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. *(MS-PS1-b)*,(MS-PS2-c),*(MS-PS3-c)*
RST.6-8.7	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-j),*(MS-PS1-g),(MS-PS3-a)*
RST.6-8.8	Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. *(MS-LS4-j),*
RI.7.8	Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims. *(MS-LS4-j)*
RI.8.3	Analyze how a text makes connections among and distinctions between individuals, ideas, or events (e.g., through comparisons, analogies, or categories). *(MS-PS1-g),(MS-PS3-a)*
WHST.6-8.1	Write arguments focused on discipline-specific content. *(MS-LS4-j),(MS-LS2-i)*
WHST.6-8.1	Write arguments to support claims with clear reasons and relevant evidence. *(MS-LS2-g)*
WHST.6-8.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
WHST.6-8.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. *(MS-LS4-j),((MS-LS2-i),(MS-LS2-g)*
WHST.6-8.7	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-LS4-i)*, (MS-LS4-j),(MS-LS2-i),*(MS-PS1-b)*
WHST.6-8.8	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 while avoiding plagiarism and providing basic bibliographic information for sources. *(MS-LS2-g)*
SL.6.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly. *(MS-LS2-g)*
SL.6.3	Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not. *(MS-LS4-j)*
SL.6-7.3	Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not. *(MS-LS2-g)*
SL.6-7.4	Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation. *(MS-LS2-g)*
SL.8.1	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-j)*
SL.7.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation. *(MS-LS4-j),(MS-LS2-i)*

Mathematics –

MP 1	Make sense of problems and persevere in solving them (MS-PS2-c),(MS-PS3-c),(MS-PS3-g)
MP.2	Reason abstractly and quantitatively. (MS-PS1-g), (MS-PS2-a),(MS-PS3-a)
MP.3	Construct viable arguments and critique the reasoning of others. *(MS-LS2-g)*
MP.4	Model with mathematics. (MS-PS2-a)
MP.5	Use appropriate tools strategically. *(MS-PS1-g)*,(MS-PS2-c),(MS-PS3-a)
5.MD	Represent and interpret data. (MS-PS3-a)
5.OA	Analyze patterns and relationships.
6.RP	Understand ratio concepts and use ratio reasoning to solve problems. (MS-PS2-c),*(MS-PS3-a)*
6.EMS-PS3-C	Represent and analyze quantitative relationships between dependent and independent variables. (MS-PS3-a)
6.EMS-PS3-A.1	Write and evaluate numerical expressions involving whole-number exponents. (MS-PS3-a)
6.EMS-PS3-A.2c	Evaluate expressions at specific values of their variables. *(MS-PS3-a)*
6.EE	Represent and analyze quantitative relationships between dependent and independent variables. *(MS-PS1-b)*
6.SP	Develop understanding of statistical variability (MS-PS1-b)
7.RP	Analyze proportional relationships and use them to solve real-world and mathematical problems. (MS-PS2-c),*(MS-PS3-a)*
7.EE	Solve real-life and mathematical problems using numerical and algebraic expressions and equations. (MS-PS2-c)
7.SP.3	Draw informal comparative inferences about two populations.
8.F	Use functions to model relationships between quantities.
8.EE	Understand the connections between proportional relationships, lines, and linear equations. (MS-PS2-c)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

HS.Structure and Properties of Matter

HS.Structure and Properties of Matter

Students who demonstrate understanding can:

HS-PS1-a. Evaluate the merits of different atomic and molecular representations based on their ability to explain a given property of matter or phenomenon. [Clarification Statement: Types of atomic and molecular structural representations can include computer-based simulations, physical, ball and stick, and drawings. Properties of matter can include melting points, boiling points, and polarity. Phenomena can include formation of solutions and phase changes.] [Assessment Boundary: Computational models and advanced conceptual models (e.g., molecular orbital theory) are not assessed.]

HS-PS1-b. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outer energy level of atoms. [Clarification Statement: An example of a pattern that predicts element properties would be Group I of the periodic table. These elements all have one electron in the outermost energy level and as such, are all highly reactive metals. Other properties could include types of bonds formed with other elements, number of bonds formed, and reactions with oxygen.] [Assessment Boundary: Only for main group elements (not transition metals). Ionization energy is not required.]

HS-PS1-c. Analyze and interpret provided data about bulk properties of various substances to support claims about the relative strength of the interactions among particles in the substance. [Clarification Statement: Students should infer the strength of interactions between particles. Bulk properties of substances can include melting point and boiling point, vapor pressure, and surface tension. Only the following types of particles are included in data and explanations: atoms, monatomic ions, and molecules.] [Assessment Boundary: Provided data is limited to the macroscopic scale. Comparisons require understanding of interactions between ions, interactions between atoms to form molecules or networked materials, and interactions between molecules; however, names of specific intermolecular forces (e.g., dipole-dipole) will not be assessed.]

HS-PS2-f. Produce technical writing and/or oral presentations about why the molecular-level structure is important in the functioning of designed materials. [Clarification Statement: Descriptions could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, hard durable materials are made of cross-linked long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Memorization of specific structures of designed molecules is not intended.]

HS-PS1-d. Develop a representation to show that energy is required to separate the atoms in a molecule and that energy is released when atoms at a distance come together to form molecules that are more stable. [Clarification Statement: Examples of representations can include drawings, graphs, chemical equations, and diagrams from data. At times, two representations would be appropriate.] [Assessment Boundary: Representations are only of common substances (e.g., water, carbon dioxide, common hydrocarbons, sodium chloride).]

HS-PS1-j. Develop representations of the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. [Clarification Statement: Representations should be qualitative.] [Assessment Boundary: Mathematical representations or quantitative calculation of energy released during nuclear processes are not assessed. Radioactive decays limited to alpha, beta, and gamma.]

HS-PS3-g. Evaluate the benefits and drawbacks of nuclear processes compared to other types of energy production. [Clarification Statement: Students are provided with data and information (e.g., input/output data, production, storage costs) about energy production methods (e.g., burning coal or solar energy generation versus using nuclear reactors).] [Assessment Boundary: Students only evaluate data and information provided. Benefits and drawbacks only include economic, safety, and environmental.]

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

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. (HS-PS1-d)
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. (HS-PS1-j)
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems. (HS-PS1-b)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS1-c)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Critique and evaluate competing arguments, models, and/or design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. (HS-PS1-a)
- Evaluate a claim for a design solution to a real-world problem based on scientific knowledge, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Disciplinary Core Ideas

PS1.A: 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. (HS-PS1-a)
- 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. (HS-PS1-b)
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-a),(HS-PS1-c),*(secondary to HS-PS2-f)*
- Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (HS-PS1-d)

PS1.C: Nuclear Processes

- Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-j)

PS2.B: Types of Interactions

- 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. (secondary to HS-PS1-a),(secondary to HS-PS1-c),(HS-PS2-f)

PS3.D: Energy in Chemical Processes and Everyday Life

- All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. (HS-PS3-g)

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.
- Systems can be designed to cause a desired effect.
- Changes in systems may have various causes that may not have equal effects. (HS-PS1-b),(HS-PS1-d)
  - Clarification Statement for HS-PS1-b: The likelihood of interactions between elements is caused by the number of electrons in their valence shell; thus, the arrangement of the periodic table.
  - Clarification Statement for HS-PS1-d: Stability is caused by minimization of energy.

Systems and System Models

- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (HS-PS1-a)

Energy and Matter

- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-j)

Structure and Function

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS1-c),(HS-PS2-f)

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HS.Structure and Properties of Matter

<table>
<tr>
<td>(HS-PS3-g)
Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.
▪ Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system. (HS-PS2-f)</td>
<td></td>
<td>○ Clarification Statement for HS-PS1-c: The relative strength of interactions among particles causes different bulk properties.
Stability and Change
▪ Much of science deals with constructing explanations of how things change and how they remain stable.
▪ Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
▪ Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability. (HS-PS3-g)

Connections to Nature of Science

Science is a Way of Knowing
▪ Science knowledge has a history that includes the refinement of, and changes to, theories, ideas, and beliefs over time. (HS-PS1-b)
Science Addresses Questions About the Natural and Material World.
▪ Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-PS3-g)
▪ Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-PS3-g)
▪ Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-PS3-g)</td>
</tr>
</table>

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-PS1-a)*,(HS-PS1-c),*(HS-PS3-g)*
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. *(HS-PS1-a)*,(HS-PS1-c),(HS-PS1-d),(HS-PS1-j),*(HS-PS3-g)*
RST.9-10.8	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. *(HS-PS1-a),(HS-PS3-g)*
WHST.11-12.1	Write arguments focused on discipline-specific content. *(HS-PS1-a),(HS-PS3-g)*
WHST.11-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-PS2-f)*
WHST.11-12.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. *(HS-PS1-a)*, (HS-PS2-f)
WHST.9-10.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation. *(HS- PS1-a)*,(HS-PS2-f),*(HS-PS3-g)*
WHST.11-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS1-a),(HS-PS3-g)
SL.9-10.2	Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. *(HS-PS2-f) (HS-PS1-a)*,(HS-PS1-c),*(HS-PS3-g)*
SL.9-10.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-PS2-f)*

Mathematics –

MP.2	Reason abstractly and quantitatively. (HS-PS1-b),(HS-PS1-c)
MP.3	Construct viable arguments and critique the reasoning of others. (HS-PS1-a),(HS-PS3-g)
MP.4	Model with mathematics. *(HS-PS1-b)*
8.SP	Investigate patterns of association in biivariate data. (HS-PS1-b)
F.LE	Construct and compare linear, quadratic, and exponential models and solve problems. *(HS-PS1-c)*
S.ID	Summarize, represent, and interpret data on two categorical and quantitative variables (HS-PS1-c)
S.IC.B	Make inferences and justify conclusions from sample surveys, experiments, and observational studies. (HS-PS1-b),(HS-PS2-f)

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HS.Chemical Reactions

HS.Chemical Reactions

Students who demonstrate understanding can:

HS-PS1-e. Construct an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. [Clarification Statement: Evidence will come from temperature, concentration, and rate data; student reasoning should include that the factors that affect reaction rates depend on the number and the energy of the collisions between molecules.] [Assessment Boundary: Limited to simple reactions in which there are only two reactants. The quantitative relationship between rate and temperature is not required.]

HS-PS1-f. Use models to support that the release or absorption of energy from a chemical system depends upon the changes in total bond energy. [Clarification Statement: Examples of using models can include molecular level drawings and diagrams of reactions, and graphs showing the relative energies of reactants and products.] [Assessment Boundary: Calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products is not assessed.]

HS-PS1-g. Refine the design of a chemical system to specify changes in conditions that would produce increased amounts of products at equilibrium.* [Clarification Statement: Examples of designs could include different ways to increase product formation including adding reactants, or removing products. Designs should include descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of chemical systems could be nitrogen plus hydrogen producing ammonia or reactions in which water is produced – such as a simple condensation reaction.] [Assessment Boundary: Limited to simple reactions provided to students, adding or removing one reactant or product at a time. Calculating equilibrium constants and concentrations is not included. The effect of temperature on equilibrium is not included. Quantitative changes are not required.]

HS-PS1-h. Use mathematical expressions to support the explanation that atoms, and therefore mass, are conserved during a chemical reaction. [Clarification Statement: Models could include ball and stick models, computer simulations, and drawings. Using mathematical expressions includes explaining the meaning of the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Memorization and rote application of problem-solving techniques alone will not yield successful performance.] [Assessment Boundary: Complex chemical reactions are not included.]

HS-PS1-i. Construct an explanation to support predications about the outcome of simple chemical reactions, using the structure of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. [Clarification Statement: Examples of chemical reactions would include the reaction of sodium and chlorine, or carbon and oxygen, or carbon and hydrogen.] [Assessment Boundary: Chemical reactions not readily predictable from the element's position on the periodic table (i.e., the main group elements) and combustion reactions are not intended. Reactions typically classified by surface level characteristics (e.g., double or single displacement reactions) are not intended.]

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

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. (HS-PS1-f)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Apply techniques of algebra and functions to represent and solve scientific and engineering problems. (HS-PS1-h)
- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations. (HS-PS1-h)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables. (HS-PS1-e)
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-PS1-e),(HS-PS1-i)
- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-g)

Disciplinary Core Ideas

PS1.B: 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 total binding energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy. (HS-PS1-e),(HS-PS1-f)
- 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. (HS-PS1-g)
- 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. (HS-PS1-h),(HS-PS1-i)

PS3.A: Definitions of Energy

- "Chemical energy" generally is used to mean the energy that can be released or stored in chemical processes. (HS-PS1-f)

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-i)

Energy and Matter

- The total amount of energy and matter in closed systems is conserved. (HS-PS1-h)
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS1-f)

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-g)
- Change and rates of change can be quantified and modeled over very short or very long periods of time. (HS-PS1-e),(HS-PS1-g)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

HS.Chemical Reactions

Connections to other DCIs in this grade-level: will be added in future version.	
Articulation to DCIs across grade-levels: will be added in future version.	
Common Core State Standards Connections:	
ELA/Literacy –	
RST.9-10.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. *(HS-PS1-e),(HS-PS1-i)*
RST.9-10.9	Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. *(HS-PS1-e),(HS-PS1-i)*
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-PS1-e),(HS-PS1-i)
WHST.11-12. 2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-e),(HS-PS1-i)
WHST.11-12.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (HS-PS1-e),(HS-PS1-i)
WHST.9-10.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-PS1-g)*
WHST.9-10.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS1-e),(HS-PS1-i)
SL.9-10.2	Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. (HS-PS1-e),(HS-PS1-i)
Mathematics –	
MP.2	Reason abstractly and quantitatively. (HS-PS1-e),(HS-PS1-h)
MP.4	Model with mathematics. (HS-PS1-h)
8.SP	Investigate patterns of association in biivariate data. (HS-PS1-e)
S.ID	Summarize, represent, and interpret data on a single count or measurement variable (HS-PS1-e),(HS-PS1-h)
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies. (HS-PS1-e),(HS-PS1-h),(HS-PS1-i)
A-CED.1	Create equations that describe numbers or relationships. (HS-PS1-h)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

HS.Forces and Interactions

Students who demonstrate understanding can:

HS-PS2-a. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on macroscopic objects, their mass, and acceleration.* [Assessment Boundary: Restricted to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

HS-PS2-b. Use mathematical expressions to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Conservation of momentum is the focus. Using mathematical expressions includes explaining the meaning of those expressions. Desired quantities are the total momentum of the system before and after interaction.] [Assessment Boundary: Systems are restricted to two macroscopic bodies moving in one dimension.]

HS-PS2-c. Design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* [Clarification Statement: Evaluation and refinement could consist of determining the success of the device at protecting the object from harm, and modifying the design to improve it. Examples include an egg drop investigation and design of a football helmet.] [Assessment Boundary: Evaluations are qualitative only.]

HS-PS2-d. Use mathematical expressions to represent the relationship between the variables in both Newton's Law of Gravitation and Coulomb's Law, and use these expressions to predict the gravitational and electrostatic forces between objects. [Clarification Statement: Using mathematical expressions includes specifying relationships in both quantitative and conceptual terms.] [Assessment Boundary: Only systems with two objects are considered.]

HS-PS2-e. Design and conduct an investigation to support claims about how electric and magnetic fields are created. [Clarification Statement: An example investigation would be experiments to determine the effect of an electrical current on a compass, or the effect of a moving magnet on a nearby conductor.] [Assessment Boundary: Qualitative observations only. In-depth understanding of fields is not intended—understanding is limited to the concept that a field is a way for objects to exert forces without touching. Students are only assessed on designing and conducting investigations with provided materials and tools.]

HS-PS3-e. Develop and use models of two objects interacting through a field to explain the changes in energy and the forces between the objects due to the interaction. [Clarification Statement: The emphasis of the core idea is on the relative position, not mass or charge. Representations could include drawings, diagrams, and texts. An example would be drawings of what happens when two charges of opposite polarity are near each other, including an explanation of how the change in energy of the charges is related to the change in energy of the field.] [Assessment Boundary: Only systems containing two objects are to be assessed.]

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

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. (HS-PS3-e)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-e)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-a)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations. (HS-PS2-b),(HS-PS2-d)
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems. (HS-PS2-b),(HS-PS2-d)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light. (HS-PS2-a)
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-b)
- In any system, total momentum is always conserved. (HS-PS2-b)
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-b),(HS-PS2-c)

PS2.B: Types of Interactions

- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-d)
- Forces at a distance are explained by fields permeating space that can transfer energy through space. Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-e),(secondary to HS-PS3-e)

PS3.A: Definitions of Energy

- …and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (HS-PS2-e)

PS3.C: Relationship Between Energy and Forces

- When two objects interacting through a force field change relative position, the energy stored in the force field is changed. (HS-PS3-e)
- Each force between the two interacting objects acts in the direction such that motion in that direction would reduce the energy in the force field between the objects. However, prior motion and other forces also affect the actual direction of motion. (HS-PS3-e)

ETS1.A: Defining and Delimiting an Engineering Problem

- Design criteria and constraints, which typically reflect the needs of the end-user of a technology or process, address such things as the product's or system's function (what job it will perform and how), its durability, and limits on its size and cost. (HS-PS2-c)
- 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. (HS-PS2-c)

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-a),(HS-PS2-e),(HS-PS3-e)
- Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS2-d)
- Systems can be designed to cause a desired effect. (HS-PS2-c)
- Changes in systems may have various causes that may not have equal effects. (HS-PS2-a)

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-b)

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builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories. ▪ Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS2-c) --- ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ▪ Theories and laws provide explanations in science, but theories do not with time become laws or facts. (HS-PS2-a),(HS-PS2-d) ▪ Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-a),(HS-PS2-d)	impacts. (HS-PS2-c) ▪ Testing should lead to improvements in the design through an iterative procedure. (HS-PS2-c) ▪ Both physical models and computer models can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. (HS-PS2-a) ▪ Computer models are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; in 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. (HS-PS2-a) **ETS1.C: Optimizing the Design Solution** ▪ The aim of engineering design is not simply to find a solution to a problem but to design the best solution under the given constraints and criteria. (HS-PS2-a) ▪ Testing should lead to design improvements through an iterative process, and computer simulations are one useful way of running such tests. (HS-PS2-a)	

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.3	Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. (HS-PS2-a),(HS-PS2-e)
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-PS2-b),(HS-PS2-d)
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-c)
WHST.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-a),(HS-PS2-e)
SL.11-12.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (HS-PS3-e)

Mathematics –

MP.2	Reason abstractly and quantitatively (HS-PS2-a),(HS-PS2-b),(HS-PS2-d)
MP.4	Model with mathematics. (HS-PS2-d)
8.F	Define, evaluate, and compare functions. *(HS-PS2-a)*,(HS-PS2-b),(HS-PS2-d)
S.ID	Summarize, represent, and interpret data on a single count or measurement variable (HS-PS2-b),(HS-PS2-d)
A.CED.1	Create equations that describe numbers or relationships. (HS-PS2-b),(HS-PS2-d)
F.BF	Build a function that models a relationship between two quantities (HS-PS2-a),(HS-PS2-b),(HS-PS2-d)
F.IF	Interpret functions that arise in applications in terms of the context. (HS-PS2-a),(HS-PS2-b),(HS-PS2-d)

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HS.Energy

HS.Energy

Students who demonstrate understanding can:

HS-PS3-a. Use mathematical expressions to describe, model, or simulate the change in the energy of one component within a closed system when the change in the energy of the other component(s) is known. [Clarification Statement: Using mathematical expressions includes explaining the meaning of those expressions.] [Assessment Boundary: Computational accounting for energy in a system is limited to systems of two or three components.]

HS-PS3-b. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* [Clarification Statement: Examples of devices can include roller coasters, Rube Goldberg devices, wind turbines, solar cells, and generators. Examples of constraints can include use of renewable energy forms and efficiency. Qualitative evaluations could include a wide range of energy conversions (e.g., from electrical to kinetic and from electromagnetic to thermal) that go beyond the expectation for quantitative evaluations.] [Assessment Boundary: Quantitative evaluation is limited to potential and kinetic conversions. Devices are limited to those constructed with materials provided to students.]

HS-PS3-c. Develop a model that supports the explanation that all forms of energy can be described as either the movement of particles or energy in fields. [Assessment Boundary: Mathematical models representing field energies are not assessed.]

HS-PS3-d. Design and conduct an investigation to support the claim that the transfer of thermal energy between components results in a more uniform energy distribution among the components of a closed system. [Clarification Statement: Investigations could include mixing liquids at different initial temperatures, adding hot objects at different temperatures to water. Evidence stems from analyzing data and using mathematical thinking to describe the energy changes both quantitatively and conceptually.] [Assessment Boundary: Assessment to be based on a given set of materials and tools.]

HS-PS3-f. Produce written and illustrated texts or oral presentations about how scientific discoveries about the conversion of energy from one form to another have affected human civilization, including the further development of science and technology.

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

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.
- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. (HS-PS3-c)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.
- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. (HS-PS3-d)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models, or simulations. (HS-PS3-a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.
- Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS3-b)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information

Disciplinary Core Ideas

PS3.A: Definitions of Energy
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-a)
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. "Mechanical energy" generally refers to some combination of motion and stored energy in an operating machine. (HS-PS3-b)
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-c)

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

PS3.D: Energy in Chemical Processes
- A variety of multistage physical and chemical processes in living organisms, particularly within their cells, account for the transport and transfer (release or uptake) of energy needed for life functions.)All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. (HS-PS3-f)
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed

Crosscutting Concepts

Systems and System Models
- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-PS3-a),(HS-PS3-c),(HS-PS3-d)
- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (HS-PS3-a),(HS-PS3-d)
  - Clarification Statement for all PEs: Energy transfer cannot be directly studied – a model must be used. In design for maximal or minimal energy transfer, the boundaries of a system must be defined

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Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS3-f)
- Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-PS3-f)

Influence of Science, Engineering, and Technology on Society and the Natural World
- Modern civilization depends on major technological systems such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. (HS-PS3-b),(HS-PS3-f)
- Widespread adoption of technological innovations often depends on market forces or other societal demands, but it may also be subject to evaluation by scientists and engineers and to eventual government regulation. (HS-PS3-b),HS-PS3-f)
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-PS3-b),(HS-PS3-f)

Connections to Nature of Science

Science Addresses Questions About the Natural

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in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system. (HS-PS3-f)

to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing the task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts. (HS-PS3-b),(HS-PS3-d)

ETS1.A: Defining and Delimiting an Engineering Problem

- Design criteria and constraints, which typically reflect the needs of the end-user of a technology or process, address such things as the product's or system's function (what job it will perform and how), its durability, and limits on its size and cost. (HS-PS3-b)
- 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. (HS-PS3-b)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges may also have manifestations in local communities. But, whatever the scale, the first things that engineers do is define the problem and specify the criteria and constraints for potential solutions. (HS-PS3-b),(HS-PS3-f)

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-PS3-b)
- Testing should lead to improvements in the design through an iterative procedure. (HS-PS3-b)

ETS1.C: Optimizing the Design Solution

- The aim of engineering design is not simply to find a solution to a problem but to design the best solution under the given constraints and criteria. (HS-PS3-b)
- Testing should lead to design improvements through an iterative process, and computer simulations are one useful way of running such tests. (HS-PS3-b)

and Material World

- Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-PS3-f)
- Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-PS3-f)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RST.9-10.3	Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text. (HS-PS3-d)
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. *(HS-PS3-a),*(HS-PS3-c)
WHST.9-10.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-PS3-b),*(HS-PS3-d)
SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. *(HS-PS3-b)*
SL.9-10.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-PS3-c)*

Mathematics –

MP.1	Make sense of problems and persevere in solving them. (HS-PS3-b)(HS-PS3-f)
MP.2	Reason abstractly and quantitatively. (HS-PS3-a),(HS-PS3-b),(HS-PS3-d)
MP.6	Attend to precision (HS-PS3-b)
S.ID	Summarize, represent, and interpret data on a single count or measurement variable *(HS-PS3-b),*(HS-PS3-d)
F.BF	Build a function that models a relationship between two quantities (HS-PS3-a)
F.IF	Interpret a functions that arise in applications in terms of the context. (HS-PS3-a)
A-REI.10	Represent and solve equations and inequalities graphically. *(HS-PS3-a)*
A.CED	Create equations that describe numbers or relationships. (HS-PS3-a)
N-Q	Reason quantitatively and use units to solve problems. *(HS-PS3-b)*

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HS.Waves and Electromagnetic Radiation

HS.Waves and Electromagnetic Radiation

Students who demonstrate understanding can:

HS-PS4-a. Make quantitative claims using provided data regarding the relationship among frequency and wavelength, and the speed of the wave traveling in various media. [Clarification Statement: Examples of provided data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth. Relationships are only expressed algebraically.]

HS-PS4-b. Evaluate a provided experimental design that attempts to determine the extent to which an interface between two materials meets the theoretical prediction for transmission, reflection, and refraction of waves. [Clarification Statement: Theoretical predictions are based on Law of Reflection and/or Snell's Law. Students should be provided relevant information, such as index of refraction of media and angle of incidence.] [Assessment Boundary: Restricted to light and sound waves.]

HS-PS4-c. Ask questions that challenge the relative advantages of analog vs. digital transmission of information in order to determine if the questions are testable and relevant.* [Clarification Statement: An example of different representations could include digital radio signals vs. FM signals. Advantages could include that digital information can be stored reliably in computer memory, but that analog can be easier to understand.] [Assessment Boundary: Questions are provided to students.]

HS-PS4-d. Develop a model to demonstrate that a structure can be modified to change its resonant frequency in a way that improves the structure's performance.* [Clarification Statement: Examples of models can include pictures, diagrams, or physical models. Potentially damaging resonance can involve real world examples of bridges, buildings, fences, or street signs; other examples can include musical instruments.] [Assessment Boundary: Students will be provided a structure to modify. Students are not required to solve a problem – only to apply the concept of resonant frequency to a given problem.]

HS-PS4-e. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is better than the other. [Clarification Statement: Arguments should include existing experimental evidence. Examples of a phenomenon can include resonance, interference, diffraction, or photoelectric effect.] [Assessment Boundary: Limited to understanding that quantum theory relates the two models, students do not need to know the specifics of the quantum theory.]

HS-PS4-f. Develop and defend a claim about the effectiveness of a particular wavelength of an electromagnetic wave for use in a certain application.* [Clarification Statement: Examples can include infrared light for night vision, x-rays being used for bone imaging, or radio waves being used for long distance communication.] [Assessment Boundary: Only qualitative descriptors in the explanation are assessed.]

HS-PS4-g. Evaluate claims in written materials about the effects that different wavelengths of electromagnetic radiation have when interacting with matter. [Clarification Statement: Examples of written materials can include trade books, magazines, web resources, and other passages that may reflect bias. Evaluations should include the idea that different wavelengths of light have different energies, and that high energy electromagnetic radiation is much more damaging to living tissue than is low energy, which is often converted to thermal energy.] [Assessment Boundary: Only radio, microwaves, infrared, visible, UV, gamma, and x-ray radiation are intended; qualitative descriptions only.]

HS-PS4-h. Construct an explanation, using the particle model of light, of how photovoltaic materials work and describe their application in everyday devices in diverse contexts.* [Clarification Statement: Everyday devices can include solar cells and photosensors.] [Assessment Boundary: Qualitative explanations only. Knowledge of band theory is not required.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design solutions using models and simulations.
- Ask and evaluate questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-c)

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. (HS-PS4-d)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.
- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS4-b)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and

Disciplinary Core Ideas

PS3.D: Energy in Chemical Processes
- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary to HS-PS4-h)

PS4.A: Wave Properties
- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of these properties. (HS-PS4-a),(HS-PS4-b)
- Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. (HS-PS4-c)
- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-c)
- Resonance is a phenomenon in which waves add up in phase in a structure, growing in amplitude due to energy input near the natural vibration frequency. Structures have particular frequencies at which they resonate. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments. (HS-PS4-d)

PS4.B: Electromagnetic Radiation
- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Quantum theory relates the two models. (Boundary: Quantum theory is not explained further at this grade level.) (HS-PS4-e)
- Because a wave is not much disturbed by objects that are small compared with its wavelength, visible light cannot be used to see such objects as individual atoms. (HS-PS4-f)
- All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium. (HS-PS4-a)

Crosscutting Concepts

Structure and Function
- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.
- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-PS4-a),(HS-PS4-b),(HS-PS4-d),(HS-PS4-e), (HS-PS4-f),(HS-PS4-g),(HS-PS4-h)
  - Clarification Statement for HS-PS4-e: The way something functions, (e.g., visible light) can be best understood through a particular representation of its structure.

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-h)

Influence of Engineering, Technology, and Science on Society and the Natural World
- Modern civilization depends on major

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

theories.

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables. (HS-PS4-a)
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-PS4-h)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of the arguments. (HS-PS4-e),(HS-PS4-f)
- Make and defend a claim about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. (HS-PS4-f)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-PS4-g)

Connections to Nature of Science

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

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

- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). (HS-PS4-g)
- Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-g)
- Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-h)
- Atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities. (HS-PS4-h)

PS4.C: Information Technologies and Instrumentation

- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-f)
- Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communication, and information technologies. (Boundary: Details of quantum physics are not formally taught at this grade level.) (HS-PS4-f)

ETS1.A: Defining and Delimiting an Engineering Problem

- Design criteria and constraints, which typically reflect the needs of the end-user of a technology or process, address such things as the product's or system's function (what job it will perform and how), its durability, and limits on its size and cost. (HS-PS4-c),(HS-PS4-d),(HS-PS4-f)
- 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. (HS-PS4-c),(HS-PS4-d),(HS-PS4-f)

ETS1.B: Developing Possible Solutions

- To design something complicated one may need to break the problem into parts and attend to each part separately but must then bring the parts together to test the overall plan. (HS-PS4-f)
- Testing should lead to improvements in the design through an iterative procedure. (HS-PS4-d)
- Both physical models and computer models can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. (HS-PS4-d)

ETS1.C: Optimizing the Design Solution

- 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. (HS-PS4-f)
- The comparison of multiple designs can be aided by a trade-off matrix. (HS-PS4-f)

technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. (HS-PS4-c),(HS-PS4-d),(HS-PS4-f),(HS-PS4-h)

- Engineers continuously modify these systems to increase benefits while decreasing costs and risks. (HS-PS4-d)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:
ELA/Literacy –

RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-PS4-a)
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS4-a)
RST.9-10.8	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-g),(HS-PS4-f), (HS-PS4-g)
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. *(HS-PS4-c), (HS-PS4-b),* (HS-PS4-E), (HS-PS4-g),
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *(HS-PS4-d),*(HS-PS4-f),(HS-PS4-h)
WHST.11-12.1	Write arguments focused on discipline-specific content. *(HS-PS4-f)*
WHST.11-12.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (HS-PS4-f)
WHST.11-12.9	Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS4-f)*
SL.9-10.1c	Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions. *(HS-PS4-c)*
SL.9-10.2	Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. *(HS-PS4-b),* (HS-PS4-f), (HS-PS4-g), (HS-PS4-h)
SL.9-10.4	Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task. HS-PS4-f), (HS-PS4-h)

Mathematics –

MP.3	Construct viable arguments and critique the reasoning of others. (HS-PS4-e),(HS-PS4-f),(HS-PS4-g)
MP.4	Model with mathematics. *(HS-PS4-a),(HS-PS4-d)*
MP.5	Use appropriate tools strategically. (HS-PS4-b)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

HS.Waves and Electromagnetic Radiation

N-Q	Reason quantitatively and use units to solve problems (HS-PS4-a)
S.ID	Summarize, represent, and interpret data on a single count or measurement variable (HS-PS4-a)
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies *(HS-PS4-b)*,(HS-PS4-e),(HS-PS4-f),(HS-PS4-h)
F.IF	Interpret functions that arise in applications in terms of the context. (HS-PS4-a)
F.BF	Build a function that models a relationship between two quantities. (HS-PS4-a)
F.LE	Construct and compare linear, quadratic, and exponential models and solve problems. *(HS-PS4-a)*
A.CED	Create equations that describe numbers or relationships. (HS-PS4-a)
A-REI.10	Represent and solve equations and inequalities graphically. *(HS-PS4-a)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

HS.Structure, Function, and Information Processing

HS.Structure, Function, and Information Processing

Students who demonstrate understanding can:

HS-LS1-a. Critically read scientific literature and produce scientific writing and/or oral presentations that communicate how the structure and function of systems of specialized cells within organisms help perform the essential functions of life. [Clarification Statement: Emphasis is on identifying systems of specialized cells or tissues (e.g., nervous, muscular, connective, epithelial) and specialized structures that these cells possess that are vital to their functioning in carrying out essential life processes (e.g., transmission of neural impulses, muscle contraction, maintenance of blood glucose levels). Students should be able to determine information that is relevant to how the structure and function of these systems are related to chemical reactions that take place between different types of molecules (e.g., water, proteins, carbohydrates, lipids, nucleic acids).] [Assessment Boundary: The assessment should measure students' understanding of the hierarchical and structural organization of cells. Emphasis is not on whole body systems or biochemistry.]

HS-LS1-b. Critically read scientific literature and produce scientific writing and/or oral presentations that communicate how DNA sequences determine the structure and function of proteins, which carry out most of the work of the cell. [Clarification Statement: Emphasis is on the conceptual understanding that DNA sequences determine the amino acid sequence; thus, protein structure and function.] [Assessment Boundary: The assessment should provide evidence of students' abilities to read critically and identify key ideas and major conceptual ideas of the relationship between structure and the processes that lead to protein synthesis. The specific steps of transcription and translation or actual protein structure are not assessed.]

HS-LS1-c. Develop and use a model to support explanations about the hierarchical organization of interacting systems working together to provide specific functions within multicellular organisms. [Clarification Statement: Emphasis is on the levels of organization including cells, tissues, organs, and systems of an organism.] [Assessment Boundary: The assessment should provide evidence of students' abilities to develop and use models to explain how each level is dependent on the next to operate as a system carrying out specific functions necessary for life.]

HS-LS1-d. Design and conduct an investigation to gather evidence in supporting explanations for the function of feedback mechanisms to maintain homeostasis. [Clarification Statement: The emphasis is on investigations (e.g., heart rate response to exercise, blood vessels response to temperature changes) that students use to provide evidence to support explanations of types of feedback.] [Assessment Boundary: The assessment should provide evidence that students can distinguish between evidence supporting the feedback mechanism and evidence that does not include a feedback mechanism. Additionally, students should be able to determine whether or not an investigation is safe and ethical. The assessment should provide evidence of students' abilities to distinguish between supporting and irrelevant data. Cellular operations involved in the feedback mechanism are not assessed.]

HS-LS1-k. Produce technical writing to communicate information about the evidence from technologies that supports explanations for the integrated functioning of various regions of the brain.* [Clarification Statement: Emphasis is on evaluating evidence about the integrated functioning of various regions of the brain and the technologies (e.g., MRI, CAT scan) used to gather the evidence about how the brain functions.] [Assessment Boundary: The assessment should provide evidence of students' abilities to determine which explanations are supported by valid and reliable data and the sources of the data. Emphasis is on physiological function, not the value of the behavior to the organism.]

HS-LS1-l. Ask questions to establish the strength of evidence supporting scientific arguments for the patterns of behavior in organisms related seeking rewards, avoiding punishments, and/or forming attachments to members of their own species and, in some cases, to members of other species. [Clarification Statement: Emphasis is on the strength of arguments explaining the relationship between brain circuits and motivation of behaviors. Emphasis is on the strength of evidence used to support an argument.] [Assessment Boundary: The assessment should provide evidence of students' abilities to recognize patterns of behaviors and relate those patterns to information processing regions of the brain and whether the organisms are seeking rewards, avoiding punishments, and/or forming attachments. The assessment will provide evidence of students' abilities to recognize patterns of behaviors and relate those patterns to the integrated functioning of the brain and whether the organism is seeking rewards, avoiding punishments, and/or forming attachments.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades 9–12 builds on grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design solutions using models and simulations.

- Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results. (HS-LS1-l)
- Ask and evaluate questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (HS-LS1-l)

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. (HS-LS1-c)
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. (HS-LS1-c)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 9-12 builds on K-8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.

- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-LS1-d)

Disciplinary Core Ideas

LS1.A: Structure and Function

- Systems of specialized cells within organisms help them perform the essential functions of life, which involve chemical reactions that take place between different types of molecules, such as water, proteins, carbohydrates, lipids, and nucleic acids. (HS-LS1-a)
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (HS-LS1-b)
- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1-c)
- Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Outside that range (e.g. at too high or too low external temperature, with too little food or water available) the organism cannot survive. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1-d)

LS1.D: Information Processing

- In complex animals, the brain is divided into several distinct regions and circuits, each of which primarily serves dedicated functions, such as visual perception, auditory perception, interpretation of perceptual information, guidance of motor movement, and decision making about actions to take in the event of certain inputs. (HS-LS1-k)
- In addition, some circuits give rise to emotions and memories that motivate organisms to seek rewards,

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS1-l)

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS1-c)

Structure and Function

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-LS1-a)
- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-LS1-b)

Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system. (HS-LS1-d)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering,

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

HS.Structure, Function, and Information Processing

- Select appropriate tools to collect, record, analyze, and evaluate data. (HS-LS1-d)
- Design and conduct investigations and test design solutions in a safe and ethical manner including considerations of environmental, social, and personal impacts. (HS-LS1-d)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (HS-LS1-a),(HS-LS1-b)
- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-LS1-a),(HS-LS1-k)
- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system. (HS-LS1-a),(HS-LS1-b)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science disciplines share common rules of evidence used to evaluate explanations about natural systems. (HS-LS1-l)
- Science includes the process of coordinating patterns of evidence with current theory. (HS-LS1-l)
- Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-LS1-l)

avoid punishments, develop fears, or form attachments to members of their own species and, in some cases, to individuals of other species (e.g., mixed herds of mammals, mixed flocks of birds). (HS-LS1-l)

- The integrated functioning of all parts of the brain is important for successful interpretation of inputs and generation of behaviors in response to them. (HS-LS1-k)

and Technology

- Science and engineering complement each other in the cycle of research and development. (HS-LS1-k)

Connections to other topics in this grade-level: will be added in future version.

Articulation across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. *(HS-LS1-a), (HS-LS1-k)*

RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text. *(HS-LS1-d)*

RI.9-10.8 Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning. (HS-LS1-a), (HS-LS1-b)

RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. *(HS-LS1-a),(HS-LS1-k)*

RST.9-10.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. *(HS-LS1-a), (HS-LS1-k)*

WHST.9-10.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-a),(HS-LS1-b),(HS-LS1-k)

WHST.9-10.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (HS-LS1-a),(HS-LS1-b),(HS-LS1-k)

WHST.9-10.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation. (HS-LS1-a),(HS-LS1-b),(HS-LS1-k)

WHST.9-10.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-a), (HS-LS1-b)

SL.9-10.2 Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. (HS-LS1-a),(HS-LS1-b),(HS-LS1-k)

SL.9-10.1c Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions. (HS-LS1-l)

SL.9-10.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-LS1-a), (HS-LS1-b), (HS-LS1-k)

Mathematics –

S.ID Summarize, represent, and interpret data on two categorical and quantitative variables. (HS-LS1-l)

S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies. (HS-LS1-l)

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HS.Inheritance and Variation of Traits

HS.Inheritance and Variation of Traits

Students who demonstrate understanding can:

HS-LS3-a. Ask questions to obtain information about the role of DNA and chromosomes in coding the instructions for forming the characteristic traits of species passed from parents to offspring. [Clarification Statement: Emphasis is on the practice of asking scientific questions and obtaining reliable information to describe roles of chromosomes and DNA in coding instructions for traits in species.] [Assessment Boundary: The assessment should provide evidence of students' abilities to ask questions and obtain relevant information about the coding of instructions for the passing of traits from parent to offspring. Assessments should not include the phases of meiosis.]

HS-LS1-e. Use a model to support the explanation of how mitotic cell division results in daughter cells with identical patterns of genetic material essential for producing and maintaining a complex organism. [Clarification Statement: Emphasis is on conceptual understanding that mitosis passes on genetically identical materials via replication, not on the phases of mitosis.] [Assessment Boundary: The assessment should provide evidence of students' abilities to explain from a model (e.g., diagrams, computer simulations) how cells may have differentiated within an organism but are genetically identical.]

HS-LS1-f. Construct an explanation using evidence for how cell differentiation is the result of activation or inactivation of specific genes and small differences in the immediate environment of the cells; relate these concepts to potential solutions in biomedical engineering and research.* [Clarification Statement: Emphasis is limited to the concept that a single cell develops into a variety of differentiated cells and thus, a complex organism.] [Assessment Boundary: The assessment should provide evidence of students' abilities to construct an explanation about the conditions necessary for cell differentiation as well as the applications for biomedical research (e.g., cancer treatment, replacing damaged organs, engineering tissues to test drugs).]

HS-LS1-g. Develop and revise a model to support explanations about the role of cellular division and differentiation in producing and maintaining complex organisms composed of systems of tissues and organs that work together to meet the needs of the entire organism. [Clarification Statement: Emphasis is on the concept that genetically identical cells produced from a single cell during embryological development differentiate and become tissues that make up organs within organ systems working together to meet the needs of the organism.] [Assessment Boundary: The assessment should provide evidence of students' abilities to show strengths and/or limitations of a model to demonstrate the development of differentiated cells with specific functions necessary for the organism to survive. Assessments could use a computer simulation. Emphasis is not on recalling the steps of mitosis or specific gene control mechanisms.]

HS-LS3-b. Synthesize, communicate, and evaluate the validity and reliability of the claim that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. [Clarification Statement: Emphasis is on conceptual and/or simple mathematical understanding of the sources of genetic variation that are heritable. Information on genetic variation should include evidence of understanding the probability of variations and the rarity of mutations.] [Assessment Boundary: The assessment should provide evidence of students' abilities to evaluate and discuss sources of genetic variation in offspring, not the details of the mechanism's variations.]

HS-LS3-d. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. [Clarification Statement: Emphasis is on distribution and variation of traits in a population and the use of mathematics (e.g., calculations of frequencies in Punnett squares, graphical representations) to describe the distribution.] [Assessment Boundary: The assessment should provide evidence of students' abilities to use mathematical reasoning to explain the variation observed in a population as a combination of genetic and environmental factors. Hardy-Weinberg calculations are beyond the intent.]

HS-LS3-c. Evaluate the merits of competing ethical arguments for the research, development, and growth of industries based on the development of technologies that modify the genetic make-up of an organism.* [Clarification Statement: Emphasis is on comparing competing arguments based on ethical as well as scientific principles.] [Assessment Boundary: The assessment should provide evidence of students' abilities to evaluate the merits of genetic modification technologies (e.g., cloning, gene therapy, genetic engineering, selective breeding) in terms of scientific principles as well as ethical considerations and social implications. The assessment should provide evidence of students' abilities to evaluate the merits of genetic modification technologies (e.g., cloning, gene therapy, genetic engineering, selective breeding) in terms of scientific principles as well as cost, safety, and reliability as well as social and environmental impacts.]

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

Asking Questions and Defining Problems

Asking questions and defining problems in grades 9-12 builds from grades K-8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design solutions using models and simulations.

- Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results. (HS-LS3-a)

Developing and Using Models

Modeling in 9-12 builds on K-8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. (HS-LS1-e),(HS-LS1-f)
- Evaluate merits and limitations of two different models of the same proposed tool, process, or system in order to select or revise a model that best fits the evidence or design criteria. (HS-LS1-f)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS3-d)

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. (HS-LS1-e)
- As successive subdivisions of an embryo's cells occur, programmed genetic instructions and small differences in their immediate environments activate or inactivate different genes, which cause the cells to develop differently—a process called differentiation. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-f),(HS-LS1-g)
- In sexual reproduction, a specialized type of cell division called meiosis occurs that results in the production of sex cells, such as gametes in animals (sperm and eggs), which contain only one member from each chromosome pair in the parent cell. (HS-LS3-b)

LS3.A: Inheritance of Traits

- In all organisms the genetic instructions for forming

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS1-e)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS3-a),(HS-LS1-f),(HS-LS3-b),(HS-LS3-d)

Scale, Proportion, and Quantity

- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-LS3-d)

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS1-g)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

HS.Inheritance and Variation of Traits

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations. (HS-LS3-d)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-LS1-g)
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-LS1-g)
- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-LS1-g)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9-12 builds from K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.
- Critique and evaluate competing arguments, models, and/or design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. (HS-LS3-c)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9-12 builds on K-8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.
- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (HS-LS3-b)
- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-LS3-b)

species' characteristics are carried in the chromosomes. (HS-LS3-a),(HS-LS3-b)
- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. (HS-LS3-a),(HS-LS3-c)
- All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. (HS-LS1-f),(HS-LS3-d)

LS3.B: Variation of Traits
- The information passed from parents to offspring is coded in the DNA molecules that form the chromosomes. (HS-LS3-a)
- 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. (HS-LS3-b)
- 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. (HS-LS3-b)
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-d),(HS-LS3-b)

ETS1.A: Defining and Delimiting an Engineering Problem
- Design criteria and constraints, which typically reflect the needs of the end-user of a technology or process, address such things as the product's or system's function (what job it will perform and how), its durability, and limits on its size and cost. (HS-LS1-g)

ETS1.C: Optimizing the Design Solution
- When evaluating solutions, all relevant considerations, including cost, safety, reliability, and aesthetic, social, cultural, and environmental impacts, should be included. (HS-LS3-c)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects involve scientists, engineers, and others with wide ranges of expertise. (HS-LS3-c)

Influence of Engineering, Technology, and Science on Society and the Natural World
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. (HS-LS3-c)

Connections to Nature of Science

Science is a Human Endeavor
- Technological advances have influenced the progress of science and science has influenced advances in technology. (HS-LS3-c)
- Science and engineering are influenced by society and society is influenced by science and engineering. (HS-LS3-c)

Connections to other topics in this grave-level: will be added in future version.

Articulation across grade-levels: will be added in future version.

Common Core State Standards Connections:
ELA/Literacy –

RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-LS3-d)
RST.9-10.9	Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. (HS-LS3-c)
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-LS1-f),(HS-LS1-g)
WHST.9-10.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-g), (HS-LS3-b)
WHST.9-10.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-LS1-g)*
WHST.9-10.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation. (HS-LS3-b)
WHST.9-10.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS3-b)
SL.9-10.1c	Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions. (HS-LS3-a)
SL.9-10.2	Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. (HS-LS1-g),*(HS-LS3-b)*
SL.9-10.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-LS3-b)

Mathematics –

MP.2	Reason abstractly and quantitatively. (HS-LS3-d)
MP.4	Model with mathematics *(HS-LS1-f)*
F.BF	Build a function that models a relationship between two quantities. (HS-LS3-d)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

A.CED	Create equations that describe numbers or relationships. (HS-LS3-d)
S.MD	Use probability to evaluate outcomes of decisions. (HS-LS3-d)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

HS.Matter and Energy in Organisms and Ecosystems

HS.Matter and Energy in Organisms and Ecosystems

Students who demonstrate understanding can:

HS-LS1-h. Develop a model to support explanations for how photosynthesis transforms light energy into stored chemical energy. [Clarification Statement: Emphasis is on model development within the context of explaining the process of photosynthesis. Models may include diagrams and chemical equations. The focus should be on the flow of matter and energy through plants and other photosynthesizing organisms.] [Assessment Boundary: The assessment should provide evidence of students' abilities to describe the inputs and outputs of photosynthesis, not the specific biochemical steps.]

HS-LS1-i. Construct an explanation that carbon, hydrogen, and oxygen from sugar molecules produced through photosynthesis may combine with other elements to form amino acids and other large carbon-based molecules. [Clarification Statement: Emphasis is on students constructing explanations for how sugar molecules are formed through photosynthesis and the components of the reaction (i.e., carbon, hydrogen, oxygen). This hydrocarbon backbone is used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA).] [Assessment Boundary: The assessment should provide evidence of students' abilities to explain the relationship between the products of photosynthesis and their role as building blocks for the formation of macromolecules. Limited to the conceptual understanding of how the products of photosynthesis are utilized to build macromolecules. The details of the various chemical reactions are not assessed.]

HS-LS1-j. Use a model to represent and support the explanation that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of metabolism, not the specific steps.] [Assessment Boundary: The assessment should provide evidence of students' abilities to use conceptual models or diagrams to explain the inputs and outputs of metabolism. Students are not expected to identify the steps in cellular respiration.]

HS-LS2-d. Develop a mathematical model that generates data to support explanations about the flow of matter and energy among organisms in an ecosystem. [Clarification Statement: Emphasis is on data derived from models of energy stored in biomass that is transferred from one trophic level to another. The model should also account for students understanding that most of the energy is not transferred between organisms but is dissipated into the environment.] [Assessment Boundary: The assessment should provide evidence of students' abilities to develop energy pyramids, food chains, food webs, and other models from data sets.]

HS-LS2-g. Apply concepts of statistical data to develop an explanation for variations in rates of photosynthesis and cellular respiration and the resulting influence on the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. [Clarification Statement: Emphasis is on determining the data that support the role of photosynthesis and cellular respiration in the cycling of carbon (e.g., seasonal fluctuations in carbon dioxide, sinks, and sources of carbon).] [Assessment Boundary: The assessment should provide evidence of students' abilities to explain the influence of different rates of photosynthesis and cellular respiration on the carbon cycle. The emphasis is not on the specific chemical steps of photosynthesis and respiration.]

HS-LS2-e. Apply scientific knowledge and evidence to explain that elements and energy are conserved as matter cycles and energy flows through ecosystems. [Clarification Statement: Emphasis is on molecules such as carbon, oxygen, hydrogen, and nitrogen and their conservation in, for example, the water cycle or carbon cycle.] [Assessment Boundary: The assessment should provide evidence of students' abilities to present evidence-based explanations for conservation through the process of cycling of matter and flow of energy.]

HS-LS2-f. Ask questions to define a problem caused by changes in population, resources, and/or the environment that can be solved through environmental engineering of solutions specific to the competition of organisms for matter and energy.* [Clarification Statement: Emphasis is on students understanding that competition between organisms is for matter and energy to survive, grow, and reproduce.] [Assessment Boundary: The assessment should provide evidence of students' abilities to identify questions that define the problems when conditions (e.g., invasive species, predator removal, extreme weather, land use) are altered. The questions should be scientific in nature and useful in defining a problem that has an environmental engineering solution.]

HS-LS2-c. Evaluate the impact of new data on a working explanation for cycling of matter and flow of energy in anaerobic respiration and revision of the explanations in light of new data.* [Clarification Statement: Emphasis is on identifying the impact of new data on scientific explanations about the cycling of matter and flow of energy.] [Assessment Boundary: The assessment should provide evidence of students' abilities to explain how new data (e.g., observations and data of organisms living near deep ocean vents–chemosynthesis) have resulted in revisions of explanations in light of new evidence. Conceptual understanding of the cycling of matter and flow of energy in anaerobic respiration is the emphases of the assessment. The emphasis is not on the specific chemical processes of either aerobic or anaerobic respiration.]

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

Asking Questions and Defining Problems

Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design solutions using models and simulations.

- Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations. (HS-LS2-f)

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. (HS-LS1-h),(HS-LS1-j)
- Develop, revise, and use models to support explanations of relationships between systems or between components of a system. (HS-LS1-h),(HS-LS1-j)
- Use models (including mathematical and computational) to

Disciplinary Core Ideas

LS1.C: Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-h)
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-i)
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (HS-LS1-i),(HS-LS1-j)
  As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. For example, aerobic (in the presence of oxygen) cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed

Crosscutting Concepts

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS2-e)

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-i)
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS1-h),(HS-LS1-j),(HS-LS2-d),(HS-LS2-f)
- Energy drives the cycling of matter within and between systems. (HS-LS2-g),(HS-LS2-c)

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generate data to support explanations and predict phenomena, analyze systems, and solve problems. (HS-LS2-d)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS2-d)
- Evaluate the impact of new data on a working explanation of a proposed process or system. (HS-LS2-g),(HS-LS2-c)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-LS2-e)
- Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects. (HS-LS1-i)

Connections to Nature of Science

Scientific Knowledge is Open to Revision in Light of New Evidence

- Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (HS-LS2-c)

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

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-LS2-c)

that can transport energy to muscles. Anaerobic (without oxygen) cellular respiration follows a different and less efficient chemical pathway to provide energy in cells. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy loss to the surrounding environment. (HS-LS1-j),(secondary to HS-LS2-d),(secondary to HS-LS2-c)

- Matter and energy are conserved in each change. This is true of all biological systems, from individual cells to ecosystems. (secondary to HS-LS2-e)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS-LS2-c)
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain. (HS-LS2-d)
- The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; (HS-LS2-e)
- Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. (HS-LS2-d)
- Competition among species is ultimately competition for the matter and energy needed for life. (HS-LS2-f)
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-g)

PS1.B: Chemical Reactions

- Chemical processes and properties of materials underlie many important biological and geophysical phenomena. (HS-LS1-j)

PS3.D: Energy in Chemical Processes

- The main way in which that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (HS-LS2-g)
- A variety of multistage physical and chemical processes in living organisms, particularly within their cells, account for the transport and transfer (release or uptake) of energy needed for life functions.) (HS-LS1-i)

Connections to other topics in this grave-level: will be added in future version.

Articulation across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS2-e)
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-LS2-d), (HS-LS2-g)
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address question or solve a problem. *(HS-LS2-e)* , (HS-LS2-c)
RST.9-10.9	Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. (HS-LS2-e),(HS-LS2-c)
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-LS1-i),(HS-LS2-e)
WHST.11-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-i),(HS-LS2-e)
WHST.11-12.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (HS-LS1-i),(HS-LS2-e)
WHST.11-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-i),(HS-LS2-e)
SL.9-10.1c	Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions. (HS-LS2-f)
SL.9-10.2	Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. (HS-LS1-i)
SL.9-10.3	Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, identifying any fallacious reasoning or exaggerated or distorted evidence. *(HS-LS2-e)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

Mathematics –

MP.2	Reason abstractly and quantitatively. (HS-LS2-d)
MP.4	Model with Mathematics. (HS-LS2-d)
MP.5	Use appropriate tools strategically. (HS-LS2-c)
S.ID	Summarize, represent, and interpret data on a single count or measurement variable. (HS-LS2-d),(HS-LS2-c)
F.BF	Build a function that models a relationship between two quantities. (HS-LS2-d)
N-Q	Reason quantitatively and use units to solve problems. (HS-LS2-d),(HS-LS2-c)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

HS.Interdependent Relationships in Ecosystems

HS.Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

HS-LS2-a. Design and conduct an investigation to generate mathematical comparisons of factors that affect carrying capacity and biodiversity of similar ecosystems at different scales. [Clarification Statement: Emphasis is on qualitative comparison of biodiversity and carrying capacity of ecosystems (e.g., wooded lot to a forest, a small pond to a large lake).] [Assessment Boundary: The assessment should provide evidence of students' abilities to make mathematical comparisons and determine which of the factors (e.g., boundaries, resources, climate, competition) affect carrying capacity and biodiversity. Assessments should include mathematical comparisons (e.g., graphs, charts, density, dispersion, histograms, population distributions) taken from simulations or historical data sets. Students should not be expected to derive mathematical equations to make comparisons.]

HS-LS2-l. Design and conduct an investigation to test design solutions for increasing or maintaining the biodiversity of an ecosystem.* [Clarification Statement: Emphasis is on designing solutions for a proposed real world problem. The investigation could be a simulation or a performance task in the classroom.] [Assessment Boundary: The assessment should provide evidence of the students' abilities to consider environmental, personal, and social impacts as well as designing a solution and developing methods for measuring the effects of the proposed changes on the system in terms of: (1) increasing biodiversity, and (2) maintaining biodiversity.]

HS-LS2-h. Develop, revise, and use a mathematical model to support an explanation of how complex sets of interactions in ecosystems maintain relatively consistent numbers and types of organisms for long periods of time when conditions are stable. [Clarification Statement: Emphasis is on mathematical models that support stability in populations through cycles and trends.] [Assessment Boundary: The assessment should provide evidence of students' abilities to derive trends from graphical representations of population trends. The models will be used to support explanations of the nature of interactions that occur in an ecosystem and relate these interactions to the stability and change. The assessment should only use mathematical analysis of the model appropriate to the grade level.]

HS-LS2-i. Use scientific reasoning, theory, and models to link evidence to claims about the effects of modest and extreme biological or physical changes to ecosystems on the natural capacity to reestablish an ecosystem with more or less stable conditions. [Clarification Statement: Emphasis is on using evidence to support arguments for the mechanisms leading to either a more stable ecosystem or less stable ecosystem. Computational models may be used as evidence to support the argument.] [Assessment Boundary: The assessment should provide evidence of students' abilities to distinguish between evidence supporting the capacity of ecosystems to respond to modest changes (e.g., hunting, fertilizer run-off) and extreme changes (e.g., fire, flood).]

HS-LS2-j. Design, evaluate, and refine a solution for reducing negative impact of human activities on the environment and ways to sustain biodiversity and maintain the planet's natural capital.* [Clarification Statement: Emphasis is on human activities (e.g., pollution, climate change, making snow at ski areas, controlled burns, dams) that change the way ecosystems operate in terms of potential impacts on biodiversity, as well as populations. The solutions should be based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.] [Assessment Boundary: The assessment should provide evidence of students' abilities to provide reasonable explanations of what might happen as the basis for proposed engineering solutions.]

HS-LS2-k. Evaluate evidence for its merits in supporting the role of group behavior on individual and species' chances to survive and reproduce. [Clarification Statement: Emphasis is on evaluating evidence for advantages of grouping behaviors (e.g., flocking, schooling, herding) and cooperative behaviors (e.g., hunting, migrating, swarming) on survival and reproduction.] [Assessment Boundary: The assessment should provide evidence of students' abilities to: (1) distinguish between group versus individual behavior, (2) identify evidence supporting the outcomes of group behavior, and (3) develop logical and reasonable arguments based on evidence.]

HS-LS2-b. Apply concepts of statistics and probability as mathematical evidence for population changes in ecosystems to support assertions about the tentative nature of scientific explanations and the role of new evidence in revising explanations.* [Clarification Statement: Emphasis is on the difference in historical and contemporary quantitative analysis that demonstrates the changes in explanations about population fluctuations and how explanations for a change at one scale may not explain changes at another scale. Emphasis is not on students only completing mathematical calculations, but using the outcomes to reach a conclusion.] [Assessment Boundary: The assessments should provide evidence of students' abilities to analyze and interpret the effect new information has on explanations (e.g., DDT effects on raptor populations, effects of water temperature below reservoirs on fish spawning, invasive species effects when spread to larger scale).]

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

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. (HS-LS2-h)
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems. (HS-LS2-h)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.

- Design an investigation individually and collaboratively and test designs as part of building and revising models, testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. (HS-LS2-a),(HS-LS2-l)
- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-LS2-a),(HS-LS2-l)
- Design and conduct investigations and test design solutions in

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-a),(HS-LS2-b)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- 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. (HS-LS2-h)
- If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-i),(HS-LS2-b)
- Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS2-k)

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-a)
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (HS-LS2-b)

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-h),(HS-LS2-i)
- Systems can be designed for greater or lesser stability. (HS-LS2-l),(HS-LS2-j)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

a safe and ethical manner including considerations of environmental, social, and personal impacts. (HS-LS2-l)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS2-b)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level and builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations. (HS-LS2-h)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables. (HS-LS2-j)
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-LS2-j)
- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-LS2-j)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-i),(HS-LS2-k)

Connections to Nature of Science

Scientific Knowledge is Open to Revision in Light of New Evidence.

- Scientific explanations can be probabilistic. (HS-LS2-b)
- Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (HS-LS2-b)
- Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. (HS-LS2-b)

destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HS-LS2-j)

LS2.D: Social Interactions and Group Behavior

- Animals, including humans, having a strong drive for social affiliation with members of their own species and will suffer, behaviorally as well as physiologically, if reared in isolation, even if all their physical needs are met. Some forms of affiliation arise from the bonds between offspring and parents. Other groups form among peers. Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (HS-LS2-k)

LS4.D: Biodiversity and Humans

- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Biological extinction, being irreversible, is a critical factor in reducing the planet's natural capital. (HS-LS2-j)
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (HS-LS2-l),(HS-LS2-j)

ETS1.B: Developing Possible Solutions

- When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (HS-LS2-j)

ETS1.C: Optimizing the Design Solution

- The aim of engineering design is not simply to find a solution to a problem but to design the best solution under the given constraints and criteria. (HS-LS2-l)

Connections to other topics in this grade-level: will be added in future version.

Articulation across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text. (HS-LS2-a), (HS-LS2-l)

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-LS2-b)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. *(HS-LS2-j), (HS-LS2-k)*

RST.9-10.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. *(HS-LS2-i), (HS-LS2-k)*

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-LS2-j)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

HS.Interdependent Relationships in Ecosystems

WHST.11-12.1	Write arguments focused on *discipline-specific content* (HS-LS2-i),(HS-LS2-k)
WHST.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS2-a),(HS-LS2-l)
WHST.11-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS2-i),(HS-LS2-k)
SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. *(HS-LS2-j)*
SL.9-10.3	Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, identifying any fallacious reasoning or exaggerated or distorted evidence. (HS-LS2-i), (HS-LS2-k)
SL.9-10.4	Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task. (HS-LS2-h)
Mathematics –	
MP.1	Make sense of problems and persevere in solving them. (HS-LS2-a)
MP.2	Reason abstractly and quantitatively (HS-LS2-a),(HS-LS2-b)
MP.4	Model with mathematics. (HS-LS2-h)
N-Q	Reason quantitatively and use units to solve problems. (HS-LS2-a),(HS-LS2-b)
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies. (HS-LS2-h)
A-CED	Create equations that describe numbers or relationships (HS-LS2-b)
S-ID	Summarize, represent, and interpret data on two categorical and quantitative variables. (HS-LS2-b)

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HS.Natural Selection and Evolution

HS.Natural Selection and Evolution

Students who demonstrate understanding can:

HS-LS4-b. Use a model to support the explanation that the process of natural selection is the result of four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. [Clarification Statement: Emphasis is on the interrelationship of the four factors that result in natural selection. Mathematical models and simulations of changes in distribution of traits in a population at different times may be used.] [Assessment Boundary: Assessment should provide evidence of students' abilities to explain natural selection in terms of the number of organisms, behaviors, morphology, or physiology factors having a direct effect on survival and reproduction as well as ability to compete for limited resources. Mathematical models may be used to communicate the explanation.]

HS-LS4-d. Construct an explanation based on evidence for how natural selection, genetic drift, gene flow through migration, and co-evolution lead to populations dominated by organisms that are anatomically, behaviorally, and physiologically adapted to survive and reproduce in a specific environment. [Clarification Statement: Emphasis is on quantitative evidence as the basis for clarifying the difference among various processes of adaptation within populations. Data on specific environmental differences and selection for/against traits should be used. Environmental factors may include ranges of seasonal temperature, climate change, acidity, and light.] [Assessment Boundary: The assessment should measure students' abilities to differentiate types of evidence used in explanations.]

HS-LS4-c. Apply concepts of statistics and probability to support explanations for how organisms with an advantageous heritable trait tend to increase in proportion to organisms that lack this trait. [Clarification Statement: Emphasis is on mathematically analyzing changes in the numerical distribution of heritable traits in a population.] [Assessment Boundary: The assessment should provide evidence of students' abilities to analyze shifts in numerical distribution of traits as evidence to support explanations. Analysis is limited to basic statistical and graphical analysis, not gene frequency calculations.]

HS-LS4-e. Synthesize, communicate, and evaluate technical information that describes how changes in environmental conditions can affect the distribution of traits in a population causing: 1) increases in the population of some species, 2) the emergence of new species over time, and 3) the extinction of other species. [Clarification Statement: Emphasis is on changes in the environment and how these changes affect the distribution of traits in the populations. The rate of change should also be considered in the changes to the environment (e.g., deforestation, fishing, fertilizer applications, drought, and flood) and the effect on the distribution of traits.] [Assessment Boundary: The assessment should provide evidence of students' abilities to explain the cause and effect for how changes to the environment affect distribution or disappearance of traits in species.]

HS-LS4-f. Design and conduct an investigation to find patterns in data indicating the relationship between changes in the environment and natural selection. [Clarification Statement: Emphasis is on finding patterns in data that support the cause and effect relationship between changes in the environment and natural selection.] [Assessment Boundary: The assessment should provide evidence of students' abilities to present evidence-based conclusions for investigations and limitations of findings in terms of the design of an investigation, identification of relevant data, attributes of reliable and accurate measurements, and presentation of evidence-based conclusions.]

HS-LS4-a. Produce scientific writing that communicates how multiple lines of evidence, such as similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development, contribute to the strength of science theories related to natural selection and biological evolution. [Clarification Statement: Emphasis is on identifying historically reliable sources of scientific evidence contributing to the strength of the theories of natural selection and biological evolution (e.g., DNA sequencing, embryology, anatomy) and evaluating how multiple lines of evidence contribute to an understanding of evolution.] [Assessment Boundary: The assessment should provide evidence of students' abilities to evaluate the strength of the evidence.]

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

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. (HS-LS4-b)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.

- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-LS4-f)
- Use investigations to gather evidence to support explanations or concepts. (HS-LS4-f)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS4-c)

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity

- Genetic information, like the fossil record, also 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. (HS-LS4-a)

LS4.B: Natural Selection

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-b),(HS-LS4-c)
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-d),(HS-LS4-c),(HS-LS4-e)

LS4.C: Adaptation

- Natural selection is the result 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. (HS-LS4-b)
- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally,

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS4-c),(HS-LS4-f),(HS-LS4-a)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-b),(HS-LS4-d),(HS-LS4-e)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency (Regularity) in Natural Systems

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-LS4-d),(HS-LS4-a)

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HS.Natural Selection and Evolution

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-LS4-d)
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-LS4-d)
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (HS-LS4-d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (HS-LS4-e),(HS-LS4-a)
- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system. (HS-LS4-e),(HS-LS4-a)

Connections to Nature of Science

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

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-LS4-a)

and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-d),(HS-LS4-c)

- Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-e)
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-e),(HS-LS4-f)
- 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. (HS-LS4-e)

Connections to other topics in this grade-level: will be added in future version.

Articulation across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS4-c)
RST.9-10.3	Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text. (HS-LS4-f)
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-LS4-b),(HS-LS4-c)
RST.9-10.8	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-LS4-e),(HS-LS4-a)
RI.9-10.8	Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning. (HS-LS4-e), (HS-LS4-a)
WHST.9-10.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-LS4-d), (HS-LS4-e), (HS-LS4-a)*
WHST.9-10.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. *(HS-LS4-d), (HS-LS4-e), (HS-LS4-a)*
WHST.9-10.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS4-f)
WHST.9-10.8	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. *(HS-LS4-e), (HS-LS4-a)*
WHST.9-10.9	Draw evidence from informational texts to support analysis, reflection, and research. *(HS-LS4-d), (HS-LS4-e), (HS-LS4-a)*
SL.9-10.2	Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. (HS-LS4-d),(HS-LS4-e),(HS-LS4-a)

Mathematics –

MP.4	Model with mathematics. (HS-LS4-b)
N-Q	Reason quantitatively and use units to solve problems (HS-LS4-c),(HS-LS4-e)
F.LE	Construct and compare linear, quadratic, and exponential models and solve problems. (HS-LS4-b)
S.ID	Summarize, represent, and interpret data on a single count or measurement variable (HS-LS4-c)
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies (HS-LS4-c),(HS-LS4-e),(HS-LS4-a)
F.BF	Build a function that models a relationship between two quantities. (HS-LS4-c)
A.CED.1	Create equations that describe numbers or relationships (HS-LS4-c)

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HS.Space Systems

HS.Space Systems

Students who demonstrate understanding can:

HS-ESS1-b. Construct explanations based on observable astronomical data as empirical evidence of the Big Bang theory and the role the development of technologies have played in obtaining this data.* [Clarification Statement: Data include the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory: 3/4 hydrogen and 1/4 helium.]

HS-ESS1-c. Synthesize and communicate technical information about the processes by which stars produce new elements over their changing lifetimes. [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]

HS-ESS1-a. Use models to describe the sun's place in space in relation to the Milky Way galaxy and the distribution of galaxies and galaxy clusters in the Universe. [Clarification Statement: Mathematical models can focus on the logarithmic powers-of-ten relationship among the sun, its solar system, the Milky Way galaxy, the local cluster of galaxies, and the universe; these relationships can also be investigated graphically, using 2D or 3D scaled models, or through computer programs, either pre-made or student-written.] [Assessment Boundary: Details about the mapped distribution of galaxies and clusters are not assessed.]

HS-ESS1-d. Analyze data on the variability of mass and energy outputs from the sun to justify the valid and reliable scientific claim that short-term changes in the sun affect human technologies and societies.* [Clarification Statement: Data span a range of time scales including sudden solar flares and coronal mass ejections referred to as space weather, 11-year "sunspot cycles," and non-cyclic variations over centuries.] [Assessment Boundary: The solar physics of why these variations occur (solar flares, coronal mass ejections, sunspot cycles, and longer-term variations in solar output) is not assessed.]

HS-ESS1-e. Use mathematical and computational representations of natural and human-made solar system objects in order to describe their motions and predict their trajectories and/or collisions.* [Clarification Statement: The same Newtonian gravitational laws governing orbital motions apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]

HS-ESS1-f. Construct explanations from data for the formation of the solar system based on space exploration and astronomical evidence of the composition, structure, and motions of solar system bodies.* [Clarification Statement: Engineering accomplishments in space have helped to raise and answer questions about our solar system. Evidence that our solar system formed from a disk of dust and gas drawn together by gravity includes: (1) the similarity between the direction of rotation of the sun, the orbits of the planets, and the directions of the rotations of planets, (2) patterns of impact craters on planetary surfaces, (3) the composition of meteorites, some of which show the make-up of the early solar system, and (4) the distribution of matter in the solar system with metal/rock-rich objects close to the sun and ice-rich objects far from the sun.] [Assessment Boundary: Details of the sequence of the evolution of the solar system, such as the timing of the late-heavy bombardment period, are not assessed.]

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

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. (HS-ESS1-a)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-ESS1-d)
- Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. (HS-ESS1-d)

Using Mathematical and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations. (HS-ESS1-e)
- Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. (HS-ESS1-e)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- The sun is one of more than 200 billion stars in the Milky Way galaxy, and the Milky Way is just one of hundreds of billions of galaxies in the universe. (HS-ESS1-a)
- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-b)
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (NRC Framework, p. 173) (HS-ESS1-b)
- 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 star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (NRC Framework, p. 173) (HS-ESS1-b),(HS-ESS1-c),(HS-ESS1-d),(HS-ESS1-e)

ESS1.B: Earth and the Solar System

- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-e)
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. (NRC Framework, p. 175) (HS-ESS1-f)

PS3.D: Energy in Chemical Processes and Everyday Life

- Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (HS-ESS1-c)

PS4.B: Electromagnetic Radiation

- Atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities. (HS-ESS1-b)

Crosscutting Concepts

Cause and Effect

- Changes in systems may have various causes that may not have equal effects. (HS-ESS1-d)

Scale, Proportion, and Quantity

- Patterns observable at one scale may not be observable or exist at other scales. (HS-ESS1-a)

Systems and System Models

- Models (e.g., physical, mathematical and computer models) can be used to simulate systems and interactions within and between systems at different scales. (HS-ESS1-e)

Energy and Matter

- Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems. (HS-ESS1-b)
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-ESS1-c)

Connection to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-b),(HS-ESS1-e),(HS-ESS1-f)

Connection to Nature of Science

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theories. ▪ Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-ESS1-b),(HS-ESS1-f) ▪ Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (HS-ESS1-b),(HS-ESS1-f) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. ▪ Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (HS-ESS1-c) ▪ Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-ESS1-c)	**ETS1.A: Defining and Delimiting an Engineering Problem** ▪ Design criteria and constraints, which typically reflect the needs of the end user of a technology or process, address such things as the product's or system's function (what job it will perform and how), its durability and limits on its size and cost. (HS-ESS1-f) **ETS1.B: Developing Possible Solutions** ▪ Both physical models and computer models can be used in various ways to aid in the engineering design process. Physical models or prototypes are helpful in testing product ideas or the properties of different materials. (HS-ESS1-e),(HS-ESS1-f) ▪ Computer models are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify or describe a design problem; in 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. (HS-ESS1-e),(HS-ESS1-f)	**Science is a Human Endeavor** ▪ Scientific knowledge is a result of human endeavors, imagination, and creativity. (HS-ESS1-f) ▪ Individuals and teams from many nations and cultures have contributed to science and engineering advances. (HS-ESS1-f) ▪ Technological advances have influenced the progress of science and science has influenced advances in technology. (HS-ESS1-b),(HS-ESS1-f)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections: [Note: these connections will be made available soon.]
ELA/Literacy –

Mathematics –

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HS.History of Earth

HS.History of Earth

Students who demonstrate understanding can:

HS-ESS1-g. Analyze actual or simulated isotope ratios within Earth materials to make valid and reliable scientific claims about the planet's age, the ages of Earth events and rocks, and the overall time scale of Earth's history.* [Clarification Statement: Actual or simulated isotope data can be used (from materials that include igneous rocks, fossils, sedimentary layers, or ice cores) to understand how events in Earth's 4.6-billion-year history have absolute ages that can be quantified.] [Assessment Boundary: Radiometric dating techniques using complex methods such as multiple isotope ratios are not assessed.]

HS-ESS1-i. Consider the incomplete nature of Earth's rock record when analyzing and interpreting the events of Earth's distant past. [Clarification Statement: Dynamic Earth processes have destroyed most of Earth's very early rock record (e.g., erosion of land surfaces, subduction of ocean lithosphere), such that very few rocks from Earth's first billions of years remain.] [Assessment Boundary: Specific events are not assessed.]

HS-ESS1-j. Construct and revise explanations about Earth's early history based on data from ancient Earth materials, asteroids, meteorites, and other planetary surfaces. [Clarification Statement: Lunar rocks, asteroids, and meteorites have remained relatively unchanged, and they serve as proxies for conditions during Earth's earliest time periods, which likely involved high levels of volcanic activity and surface impacts, including the formation of the Moon and the Late Heavy Bombardment period.] [Assessment Boundary: Memorization of absolute time periods of Earth's past is not required.]

HS-ESS1-h. Construct explanations, using the theory of plate tectonics, for patterns in the general trends of the ages of both continental and oceanic crust. [Clarification Statement: For oceanic crust, trends of crustal ages entail the youngest seafloor rocks located at mid-ocean ridges and the oldest ocean rocks often (but not always) located near continental boundaries, with age bands of rocks parallel across mid-ocean ridges dependent upon spreading rates. For continental crust, continents such as North America contain ancient cores (cratons) with regions of increasingly younger rocks trending toward the edges as a result of subsequent plate interactions.]

HS-ESS2-l. Apply scientific reasoning, theory, and models to support the claim that dynamic causes, effects, and feedbacks among Earth's systems result in continual coevolution of Earth and the life that exists on it. [Clarification Statement: Students investigate examples of feedbacks among Earth's different systems (e.g., the atmosphere affects the conditions for life, which in turn affects the composition of the atmosphere; or, soil supports life, which in turn increases the rate of development of soil).] [Assessment Boundary: The complete ways that the biosphere interacts with Earth's other systems are not assessed; only examples are necessary.]

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

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-ESS1-g)
- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data. (HS-ESS1-g),(HS-ESS1-i)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations. (HS-ESS1-g)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables. (HS-ESS1-h)
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-ESS1-j),(HS-ESS2-l)
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-ESS1-j),(HS-ESS1-h)

Connections to Nature of Science

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

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-ESS1-h)

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth

- Radioactive-decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geologic time. (HS-ESS1-g)
- Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. (HS-ESS1-h)
- 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. (HS-ESS1-i),(HS-ESS1-j)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- *Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history.* (*ESS2.B Grade 8 GBE*) (HS-ESS1-h)

ESS2.E: Biogeology

- The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS2-l)

PS1.C: Nuclear Processes

- Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present. (HS-ESS1-g)

PS3.B: Conservation of Energy and Energy Transfer

- Any object or system that can degrade with no added energy is unstable. Eventually it will do so, but if the energy releases throughout the transition are small, the process duration can be very long (e.g., long-lived radioactive isotopes). (HS-ESS1-g)

Crosscutting Concepts

Patterns

- Empirical evidence is needed to identify patterns. (HS-ESS1-h)

Scale, Proportion, and Quantity

- Patterns observable at one scale may not be observable or exist at other scales. (HS-ESS1-i)
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g. linear growth vs. exponential growth). (HS-ESS1-g)

Stability and Change

- Change and rates of change can be quantified and modeled over very short or very long periods of time. (HS-ESS1-j)
- Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS2-l)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-g)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-ESS1-g)
- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-g)

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HS.History of Earth

▪ Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (HS-ESS1-h)		

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections: [Note: these connections will be made available soon.]
ELA/Literacy –

Mathematics –

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HS.Earth’s Systems

HS.Earth’s Systems

Students who demonstrate understanding can:

HS-ESS2-c. Apply scientific reasoning to show how empirical evidence from Earth observations and laboratory experiments have been used to develop the current model of Earth’s interior.* [Clarification Statement: Examples of evidence may include results from drill cores (rock composition with depth), gravity (density with depth), Earth’s magnetic field, seismic waves (elastic properties with depth), and laboratory experiments on Earth materials (composition, density, and elastic properties with pressure).]

HS-ESS2-d. Use a model of Earth’s interior including the mechanisms of thermal convection to support the explanation for the cycling of matter within the Earth. [Clarification Statement: Explanations of cycling of matter should focus on the plate tectonic process, with ocean lithosphere sinking down into the mantle at subduction zones and new rock coming to the surface at ocean spreading centers, but can also include non-plate tectonic processes such as hot spot mantle plumes. Models of the mechanisms should include the major forces associated with the surface expression of convection, whose impacts on Earth’s surface include land formation, volcanic activity and uplift, orogeny, basin formation, crustal deformation, and replenishment of Earth’s atmosphere and ocean.]

HS-ESS2-i. Analyze the physical and chemical properties of water to make valid scientific claims about the impact of water on the flow of energy and the cycling of matter within and among Earth systems.* [Clarification Statement: Claims about the flow of energy should include the role of water in the convective transfer of energy through oceanic and atmospheric circulation; the cycling of matter refers to both the flow of water through the various hydrologic cycles, which connect the ocean with other water reservoirs, and the many roles that water plays in moving mineral and rock materials through Earth’s systems.]

HS-ESS2-a. Use Earth system models to support explanations of how Earth’s internal and surface processes operate concurrently at different spatial and temporal scales to form landscapes and sea floor features. [Clarification Statement: The appearance of the land (e.g., mountains, basins, valleys, plateaus, platforms) and sea floor features (e.g., trenches, ridges, fracture zones, seamounts, abyssal plains, continental slopes) are a result of both constructive forces (e.g., volcanism, tectonic uplift, orogeny) and destructive mechanisms (e.g., stream processes, coastal wave action, mass wasting, weathering, erosion, shoreline progressions).] [Assessment Boundary: Details of the formation of major geographic features of Earth’s surface are not assessed.]

HS-ESS2-b. Construct an evidence-based argument about how a natural or human-caused change to one part of an Earth system can create feedback that causes changes in that system or other systems.* [Clarification Statement: Modern civilization depends on major technological systems and these are critical aspects of decisions about technology usage. Local real world examples could include how removing ground vegetation causes an increase in water runoff and soil erosion; building reservoirs increases groundwater recharge; installing a coastal rock jetty changes currents and resulting beach erosion patterns; removing wetlands causes a decrease in local humidity that further reduces the wetland extent; diminishing glacial ice reduces the amount of sunlight reflected from Earth’s surface, which increases surface temperatures and further reduces the amount of ice.]

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Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. (HS-ESS2-d),(HS-ESS2-a)
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems. (HS-ESS2-d),(HS-ESS2-a)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-ESS2-i)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-ESS2-c)
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-ESS2-b)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based on empirical evidence. (HS-

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems

- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth’s surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. (HS-ESS2-c)
- Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth’s interior and gravitational movement of denser materials toward the interior. (HS-ESS2-d)
- Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. A deep knowledge of how feedbacks work within and among Earth’s systems is still lacking, thus limiting scientists’ ability to predict some changes and their impacts. (HS-ESS2-a),(HS-ESS2-b)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- The radioactive decay of unstable isotopes continually generates new energy within Earth’s crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. (HS-ESS2-d)
- *Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth’s surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE)* (HS-ESS2-d)
- *Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth’s crust. (ESS2.B Grade 8 GBE)* (HS-ESS2-a)

ESS2.C: The Roles of Water in Earth’s Surface Processes

- 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. (HS-ESS2-i)

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ESS2-b)

ETS1.C: Optimizing the Design Solution

- The aim of engineering design is not simply to find a solution to a

Crosscutting Concepts

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS2-a)

Energy and Matter

- Energy drives the cycling of matter within and between systems. (HS-ESS2-d),(HS-ESS2-i)

Structure and Function

- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-ESS2-c)

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS2-b)

Connections to Engineering, Technology, and Applications of Science

Interaction of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS2-c)

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

- New technologies can have deep impacts on society and the environment, including some that

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ESS2-c) ▪ Science disciplines share common rules of evidence used to evaluate explanations about natural systems. (HS-ESS2-c) ▪ Science includes the process of coordinating patterns of evidence with current theory. (HS-ESS2-c)	problem but to design the best solution under the given constraints and criteria. (HS-ESS2-c) ▪ When evaluating solutions, all relevant considerations, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts, should be included. (HS-ESS2-i),(HS-ESS2-b)	were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS2-b)

Connections to other DCIs in this grade-level: will be added in future version.
Articulation to DCIs across grade-levels: will be added in future version.
Common Core State Standards Connections: [Note: these connections will be made available soon.] *ELA/Literacy –* *Mathematics –*

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HS.Weather and Climate

HS.Weather and Climate

Students who demonstrate understanding can:

HS-ESS2-j. Use models of the flow of energy between the sun and Earth's atmosphere, ocean, and land to support explanations of how Earth's radiative energy balance is affected by the absorption and retention of heat in Earth's atmosphere. [Clarification Statement: Students examine the radiative properties of different atmospheric gases and surface regions, (e.g., ocean, ice, land), and will evaluate variations in the reflection, absorption, storage, and redistribution of solar radiation among the atmosphere, ocean, and land systems.]

HS-ESS2-g. Develop, revise, and use models of atmospheric circulation to support explanations of how air masses redistribute energy from the sun. [Clarification Statement: The absorption of solar radiation by the ocean and the subsequent heat transfer due to evaporation largely drive atmospheric circulation through the generation of high- and low-pressure systems (e.g., the condensation of water vapor over warm ocean surfaces provides the power for hurricanes and typhoons). Models of atmospheric circulation should include the Coriolis effect and the locations of the continents.]

HS-ESS2-h. Design and conduct investigations to model the conditions at which clouds form and precipitation occurs, taking into account the factors of humidity, temperature, and pressure. [Clarification Statement: Weather conditions include the temperature and pressure changes that occur during orographic lifting, frontal wedging, air mass convergence, and localized convective lifting; investigations include cooling of water by adiabatic, conductive, radiational, or evaporative processes.]

HS-ESS2-k. Develop, revise, and use quantitative models to support the explanation of the amount of carbon that cycles among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Biogeochemical cycles involve the cycling of carbon and other elements through the ocean, atmosphere, soil, and biosphere, providing the foundation for living organisms.]

HS-ESS2-e. Construct a scientific explanation based on evidence from the geoscience record that changes to any Earth and Solar System processes can affect global and regional climates over a wide range of time scales.* [Clarification Statement: Examples of evidence include ice core data, tree-ring data, the fossil and sedimentary record, which show the history of surface temperatures, the ice, volume, and sea level fluctuations. Examples of the changes to processes include variations in the sun's energy output, Earth's orbit and axis orientation, tectonic events, ocean circulation, volcanic activity, glacial activity, biosphere interactions, and human activities.] [Assessment Boundary: Use evidence from the geoscience record only.]

HS-ESS2-f. Read scientific literature critically to evaluate and communicate the causes and effects of climate change over 10s-100s of years, 10s-100s of thousands of years, and 10s-100s of millions of years. [Clarification Statement: Examples of causes are changes in solar output, ocean circulation, and volcanic and human activity (which change atmospheric composition and other systems over 10s-100s of years); changes to Earth's orbit and the orientation of its axis (over 10s-100s of thousands of years); or long-term changes in atmospheric composition (over 10s-100s of millions of years).]

HS-ESS3-g. Use geoscience data and the results from global climate models to make evidence-based forecasts of climate change. [Clarification Statement: Geoscience data can include charts, tables, or maps of topography, biomass, precipitation, temperature, or weather-related events.]

HS-ESS3-h. Apply scientific reasoning, theory, and models to construct explanations for how humans may predict and modify their impacts on future global climate systems.* [Clarification Statement: Examples can range from large-scale geoengineering design solutions to alter global temperatures (e.g., seeding the atmosphere with aerosols or seeding the ocean with iron to enhance microbe growth) to more local efforts (e.g., reducing resource consumption and energy use, recycling and reusing, and using renewable energy sources) done by both societies and individuals. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.]

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

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. (HS-ESS2-j)
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. (HS-ESS2-k),(HS-ESS2-g).
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems. (HS-ESS3-g)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.

- Design and conduct investigations individually and collaboratively and test designs as part of building and revising models, supporting explanations of phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. (HS-ESS2-h)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems

- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-e),(HS-ESS2-f)
- *Weather is driven by interactions of the geosphere, hydrosphere, and atmosphere. (NRC Framework, p. 180)* (HS-ESS2-g),(HS-ESS2-h)

ESS2.D: Weather and Climate

- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. Climate change can occur when certain parts of Earth's systems are altered. (HS-ESS2-j)
- Geologic evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere; longer-term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the orientation of its axis; or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen. The time scales of these changes varied from a few to millions of years. Human activity causes changes in the atmosphere that include increased carbon dioxide concentrations and thus affect climate (link to ESS3.D). (HS-ESS2-k),(HS-ESS2-e),(HS-ESS2-f)
- Global climate models incorporate scientists' best knowledge of physical and chemical processes and of the interactions of relevant systems. They are tested by their ability to fit past climate variations. (HS-ESS3-g)
- Current models predict that, although future regional climate

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-h)
- In complex natural and designed systems, not all of the outcomes can be predicted—but outcomes might be predicted in systems when smaller scale mechanisms are known. (HS-ESS3-g)

Scale, Proportion, and Quantity

- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (HS-ESS2-f)

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-ESS2-j)

Energy and Matter

- The total amount of energy and matter in closed systems is conserved. (HS-ESS2-k)
- Energy drives the cycling of matter within and between systems. (HS-ESS2-g)

Stability and Change

- Much of science deals with

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student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-ESS3-h)
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-ESS2-e)
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (HS-ESS2-e)
- Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects. (HS-ESS3-h)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-ESS2-e)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (HS-ESS2-f)

Connections to Nature of Science

Scientific Investigations Use a Variety of Methods

- Science investigations use diverse methods and do not always use the same set of procedures to obtain data. (HS-ESS3-g)
- New technologies advance scientific knowledge. (HS-ESS3-g)
- Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. (HS-ESS3-g)

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based on empirical evidence. (HS-ESS2-e),(HS-ESS3-g)
- Science includes the process of coordinating patterns of evidence with current theory. (HS-ESS3-h)
- Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS3-h),(HS-ESS2-f)(HS-ESS3-g)

changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. Hence the outcomes depend on human behaviors (link to ESS3.D) as well as on natural factors that involve complex feedbacks among Earth's systems (link to ESS3.A). (HS-ESS3-h)

ESS3.D: Global Climate Change

- Global climate models are often used to understand the process of climate change because these changes are complex and can occur slowly over Earth's history. (HS-ESS3-g)
- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-g),(HS-ESS3-h)
- Thus science and engineering will be essential both to understanding the possible impacts of global climate change and to informing decisions about how to slow its rate and consequences–for humanity as well as for the rest of the planet. (HS-ESS3-g),(HS-ESS3-h)

ETS1.A: Defining and Delimiting an Engineering Problem

- Criteria and constraints 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. (HS-ESS3-h)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges may also have manifestations in local communities. But, whatever the scale, the first things that engineers do is define the problem and specify the criteria and constraints for potential solutions. (HS-ESS3-h)

ETS1.B: Developing Possible Solutions

- To design something complicated one may need to break the problem into parts and attend to each part separately but must then bring the parts together to test the overall plan. (HS-ESS3-h)
- 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. (HS-ESS3-h)

constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS2-e)

Connections to Engineering, Technology, and Applications of Science

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

- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS3-h)

Connections to Nature of Science

Science Addresses Questions About the Natural and Material World

- Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-h)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections: [Note: these connections will be made available soon.]
ELA/Literacy –

Mathematics –

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

HS.Human Sustainability

HS.Human Sustainability

Students who demonstrate understanding can:

HS-ESS3-a. Construct explanations based on evidence for how the development of human societies has been influenced by natural resource availability.* [Clarification Statement: Examples can be drawn from the many civilizations across history whose rise, transformation, or fall has been facilitated by the presence of or lack of these resources. Examples of key resources include the location of water (rivers, groundwater), coasts, regions of fertile soils such as deltas, and high concentrations of minerals, ores, coal, and hydrocarbons.]

HS-ESS3-b. Analyze and revise solutions for developing, managing, and utilizing resources that would increase economic, social, environmental, and/or cost: benefit ratios.* [Clarification Statement: Examples include best practices for agricultural soil use, retrieving water from aquifers or desalination, mining for coal and minerals, pumping for oil, hydro-fracturing to retrieve natural gas, recovering off-shore methane gas hydrates, extracting petroleum from tar sands and oil shales, and the conservation, recycling, and reuse of resources. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.]

HS-ESS3-e. Identify mathematical relationships between natural resource production and consumption rates in order to assess the global sustainability of humans and the biodiversity that supports them.* [Clarification Statement: Use equations for linear relationships.] [Assessment Boundary: The construction of equations is not expected for non-linear relationships, which can be studied graphically (e.g., with "Hubbert" curves) or computationally.]

HS-ESS3-i. Use models of Earth system interactions to support explanations of the relationships among the hydrosphere, atmosphere, cryosphere, geosphere, and biosphere systems and how they are being modified in response to human activities.* [Clarification Statement: Examples include: changes to groundwater levels and recharge rates; ocean acidity and coral health; atmospheric composition and rain acidity and lake life health; deforestation and erosion rates and local biosphere health; agricultural fertilization; stream composition and "dead" zones in offshore regions.] [Assessment Boundary: Students will not be required to model all the ways systems are being modified by human activities, but need to demonstrate how systems can react in response to feedbacks from human activities.]

HS-ESS3-f. Analyze data regarding the effects of human activities on natural systems to make valid scientific claims for how engineering solutions are designed and implemented to help limit environmental impacts.* [Clarification Statement: Examples of environmental impacts that have been mitigated include water and air pollution, landfill leakage, acid rain, the growth of the Antarctic ozone hole, and agricultural soil erosion. Claims can be qualitative or quantitative, in cases where quantitative data are available. New technologies enhance the ability to construct scientific claims based on evidence.]

HS-ESS3-c. Ask questions to construct and revise explanations of the impact that natural hazards and other geoscience events have had on the course of human history at regional and global scales. [Clarification Statement: Natural hazard events (e.g., earthquakes, volcanoes, floods) and changes in regional or global climates can affect populations, drive mass migrations, and influence the rise and fall of civilizations.]

HS-ESS3-d. Construct and evaluate scientific claims based on valid and reliable evidence that human activities can contribute to the frequency and intensity of some natural hazards.* [Clarification Statement: Human activities (e.g., building dams and levees, urbanizing ground cover, removing wetlands, managing fires, removing vegetation) can increase the frequency and/or severity of certain natural hazards (floods, droughts, forest fires, landslides, coastal erosion).]

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

Asking Questions and Defining Problems

Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design solutions using models and simulations.

- Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results. (HS-ESS3-c)

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. (HS-ESS3-i)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-ESS3-f)
- Evaluate the impact of new data on a working explanation of a proposed process or system. (HS-ESS3-f)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Apply techniques of algebra and functions to represent and solve scientific and engineering problems. (HS-ESS3-e)
- Create a simple computational model or simulation of a designed device, process, or system. (HS-ESS3-e)

Disciplinary Core Ideas

ESS3.A: Natural Resources

- Resource availability has guided the development of human society. (HS-ESS3-a)
- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-b)

ESS3.B: Natural Hazards

- Natural hazards and other geologic events have shaped the course of human history by destroying buildings and cities, eroding land, changing the courses of rivers, and reducing the amount of arable land. These events have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-c)
- Natural hazards can be local, regional, or global in origin, and their risks increase as populations grow. Human activities can contribute to the frequency and intensity of some natural hazards. (HS-ESS3-d)

ESS3.C: Human Impacts on Earth Systems

- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-e)
- Scientists and engineers can make major contributions [to responsible management]–for example, by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. When the source of an environmental problem is understood and international agreement can be reached, human activities can be regulated to mitigate global impacts (e.g., acid rain and the ozone hole over Antarctica). (HS-ESS3-f)

ESS3.D: Global Climate Change

- Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-c)

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-ESS3-i)

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS3-f)
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-f)
- Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS3-f)

Connections to Engineering, Technology, and Applications of Science

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

- Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. (HS-ESS3-a),(HS-ESS3-e)

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Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-ESS3-a),(HS-ESS3-c),(HS-ESS3-d)
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (HS-ESS3-a),(HS-ESS3-d)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Critique and evaluate competing arguments, models, and/or design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. (HS-ESS3-b)
- Evaluate a claim for a design solution to a real-world problem based on scientific knowledge, empirical evidence, and logical arguments regarding all relevant factors (e.g. economic, societal, environmental, and ethical considerations). (HS-ESS3-b)

and are modified in response to human activities, as well as changes in human activities. (HS-ESS3-i)

ETS1.A: Defining and Delimiting an Engineering Problem

- Criteria and constraints 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. (HS-ESS3-f)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges may also have manifestations in local communities. But, whatever the scale, the first things that engineers do is define the problem and specify the criteria and constraints for potential solutions. (HS-ESS3-b),(HS-ESS3-i)

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ESS3-b),(HS-ESS3-f)
- Testing should lead to improvements in the design through an iterative procedure. (HS-ESS3-f)

ETS1.C: Optimizing the Design Solution

- The aim of engineering design is not simply to find a solution to a problem but to design the best solution under the given constraints and criteria. (HS-ESS3-b),(HS-ESS3-f)
- 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. (HS-ESS3-e),(HS-ESS3-f)

- Engineers continuously modify these systems to increase benefits while decreasing costs and risks. (HS-ESS3-b),(HS-ESS3-f)
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. (HS-ESS3-d)

Connections to Nature of Science

Science Addresses Questions About the Natural and Material World

- Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-b)
- Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-b)
- Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-ESS3-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections: [Note: these connections will be made available soon.]
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Mathematics –

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HS.Engineering Design

HS.Engineering Design

[Note: All of these performance expectations can also be found in other standards.]

Students who demonstrate understanding can:

HS-PS2-c. Design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* [Clarification Statement: Evaluation and refinement could consist of determining the success of the device at protecting the object from harm, and modifying the design to improve it. Examples include an egg drop investigation and design of a football helmet.] [Assessment Boundary: Evaluations are qualitative only.]

HS-PS3-b. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* [Clarification Statement: Examples of devices can include roller coasters, Rube Goldberg devices, wind turbines, solar cells, and generators. Examples of constraints can include use of renewable energy forms and efficiency. Qualitative evaluations could include a wide range of energy conversions (e.g., from electrical to kinetic and from electromagnetic to thermal) that go beyond the expectation for quantitative evaluations.] [Assessment Boundary: Quantitative evaluation is limited to potential and kinetic conversions. Devices are limited to those constructed with materials provided to students.]

HS-PS4-c. Ask questions that challenge the relative advantages of analog vs. digital transmission of information in order to determine if the questions are testable and relevant.* [Clarification Statement: An example of different representations could include digital radio signals vs. FM signals. Advantages could include that digital information can be stored reliably in computer memory, but that analog can be easier to understand.] [Assessment Boundary: Questions are provided to students.]

HS-PS4-d. Develop a model to demonstrate that a structure can be modified to change its resonant frequency in a way that improves the structure's performance.* [Clarification Statement: Examples of models can include pictures, diagrams, or physical models. Potentially damaging resonance can involve real world examples of bridges, buildings, fences, or street signs; other examples can include musical instruments.] [Assessment Boundary: Students will be provided a structure to modify. Students are not required to solve a problem – only to apply the concept of resonant frequency to a given problem.]

HS-PS4-f. Develop and defend a claim about the effectiveness of a particular wavelength of an electromagnetic wave for use in a certain application.* [Clarification Statement: Examples can include infrared light for night vision, x-rays being used for bone imaging, or radio waves being used for long distance communication.] [Assessment Boundary: Only qualitative descriptors in the explanation are assessed.]

HS-LS1-f. Construct an explanation using evidence for how cell differentiation is the result of activation or inactivation of specific genes and small differences in the immediate environment of the cells; relate these concepts to potential solutions in biomedical engineering and research.* [Clarification Statement: Emphasis is limited to the concept that a single cell develops into a variety of differentiated cells and thus, a complex organism.] [Assessment Boundary: The assessment should provide evidence of students' abilities to construct an explanation about the conditions necessary for cell differentiation as well as the applications for biomedical research (e.g., cancer treatment, replacing damaged organs, engineering tissues to test drugs).]

HS-ESS1-f. Construct explanations from data for the formation of the solar system based on space exploration and astronomical evidence of the composition, structure, and motions of solar system bodies.* [Clarification Statement: Engineering accomplishments in space have helped to raise and answer questions about our solar system. Evidence that our solar system formed from a disk of dust and gas drawn together by gravity includes: (1) the similarity between the direction of rotation of the sun, the orbits of the planets, and the directions of the rotations of planets, (2) patterns of impact craters on planetary surfaces, (3) the composition of meteorites, some of which show the make-up of the early solar system, and (4) the distribution of matter in the solar system with metal/rock-rich objects close to the sun and ice-rich objects far from the sun.] [Assessment Boundary: Details of the sequence of the evolution of the solar system, such as the timing of the late-heavy bombardment period, are not assessed.]

HS-ESS3-f. Analyze data regarding the effects of human activities on natural systems to make valid scientific claims for how engineering solutions are designed and implemented to help limit environmental impacts.* [Clarification Statement: Examples of environmental impacts that have been mitigated include water and air pollution, landfill leakage, acid rain, the growth of the Antarctic ozone hole, and agricultural soil erosion. Claims can be qualitative or quantitative, in cases where quantitative data are available. New technologies enhance the ability to construct scientific claims based on evidence.]

HS-ESS3-h. Apply scientific reasoning, theory, and models to construct explanations for how humans may predict and modify their impacts on future global climate systems.* [Clarification Statement: Examples can range from large-scale geoengineering design solutions to alter global temperatures (e.g., seeding the atmosphere with aerosols or seeding the ocean with iron to enhance microbe growth) to more local efforts (e.g., reducing resource consumption and energy use, recycling and reusing, and using renewable energy sources) done by both societies and individuals. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.]

HS-PS3-f. Produce written and illustrated texts or oral presentations about how scientific discoveries about the conversion of energy from one form to another have affected human civilization, including the further development of science and technology.*

HS-ESS3-b. Analyze and revise solutions for developing, managing, and utilizing resources that would increase economic, social, environmental, and/or cost:benefit ratios.* [Clarification Statement: Examples include best practices for agricultural soil use, retrieving water from aquifers or desalination, mining for coal and minerals, pumping for oil, hydro-fracturing to retrieve natural gas, recovering off-shore methane gas hydrates, extracting petroleum from tar sands and oil shales, and the conservation, recycling, and reuse of resources. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.]

HS-ESS3-i. Use models of Earth system interactions to support explanations of the relationships among the hydrosphere, atmosphere, cryosphere, geosphere, and biosphere systems and how they are being modified in response to human activities.* [Clarification Statement: Examples include: changes to groundwater levels and recharge rates; ocean acidity and coral health; atmospheric composition and rain acidity and lake life health; deforestation and erosion rates and local biosphere health; agricultural fertilization; stream composition and "dead" zones in offshore regions.] [Assessment Boundary: Students will not be required to model all the ways systems are being modified by human activities, but need to demonstrate how systems can react in response to feedbacks from human activities.]

HS-LS2-j. Design, evaluate, and refine a solution for reducing negative impact of human activities on the environment and ways to sustain biodiversity and maintain the planet's natural capital.* [Clarification Statement: Emphasis is on human activities (e.g., pollution, climate change, making snow at ski areas, controlled burns, dams) that change the way ecosystems operate in terms of potential impacts on biodiversity, as well as populations. The solutions should be based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.] [Assessment Boundary: The assessment should provide evidence of students' abilities to provide reasonable explanations of what might happen as the basis for proposed engineering solutions.]

HS-ESS2-b. Construct an evidence-based argument about how a natural or human-caused change to one part of an Earth system can create feedback that causes changes in that system or other systems.* [Clarification Statement: Modern

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civilization depends on major technological systems and these are critical aspects of decisions about technology usage. Local real world examples could include how removing ground vegetation causes an increase in water runoff and soil erosion; building reservoirs increases groundwater recharge; installing a coastal rock jetty changes currents and resulting beach erosion patterns; removing wetlands causes a decrease in local humidity that further reduces the wetland extent; diminishing glacial ice reduces the amount of sunlight reflected from Earth's surface, which increases surface temperatures and further reduces the amount of ice.]

HS-PS2-a. **Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on macroscopic objects, their mass, and acceleration.*** [Assessment Boundary: Restricted to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

HS-ESS1-e. **Use mathematical and computational representations of natural and human-made solar system objects in order to describe their motions and predict their trajectories and/or collisions.*** [Clarification Statement: The same Newtonian gravitational laws governing orbital motions apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]

HS-LS2-l. **Design and conduct an investigation to test design solutions for increasing or maintaining the biodiversity of an ecosystem.*** [Clarification Statement: Emphasis is on designing solutions for a proposed problem. The investigation may be a simulation or a performance task in the classroom.] [Assessment Boundary: The assessment should provide evidence of the students' abilities to consider environmental, personal, and social impacts as well as designing a solution and developing methods for measuring the effects of the proposed changes on the system in terms of: (1) increasing biodiversity, and (2) maintaining biodiversity.]

HS-ESS2-c. **Apply scientific reasoning to show how empirical evidence from Earth observations and laboratory experiments have been used to develop the current model of Earth's interior.*** [Clarification Statement: Examples of evidence may include results from drill cores (rock composition with depth), gravity (density with depth), Earth's magnetic field, seismic waves (elastic properties with depth), and laboratory experiments on Earth materials (composition, density, and elastic properties with pressure).]

HS-LS3-c. **Evaluate the merits of competing ethical arguments for the research, development, and growth of industries based on the development of technologies that modify the genetic make-up of an organism.*** [Clarification Statement: Emphasis is on comparing competing arguments based on ethical as well as scientific principles.] [Assessment Boundary: The assessment should provide evidence of students' abilities to evaluate the merits of genetic modification technologies (e.g., cloning, gene therapy, genetic engineering, selective breeding) in terms of scientific principles as well as ethical considerations and social implications. The assessment should provide evidence of students' abilities to evaluate the merits of genetic modification technologies (e.g., cloning, gene therapy, genetic engineering, selective breeding) in terms of scientific principles as well as cost, safety, and reliability as well as social and environmental impacts.]

HS-ESS2-i. **Analyze the physical and chemical properties of water to make valid scientific claims about the impact of water on the flow of energy and the cycling of matter within and among Earth systems.*** [Clarification Statement: Claims about the flow of energy should include the role of water in the convective transfer of energy through oceanic and atmospheric circulation; the cycling of matter refers to both the flow of water through the various hydrologic cycles, which connect the ocean with other water reservoirs, and the many roles that water plays in moving mineral and rock materials through Earth's systems.]

HS-ESS3-e. **Identify mathematical relationships between natural resource production and consumption rates in order to assess the global sustainability of humans and the biodiversity that supports them.*** [Clarification Statement: Use equations for linear relationships.] [Assessment Boundary: The construction of equations is not expected for non-linear relationships, which can be studied graphically (e.g., with "Hubbert" curves) or computationally.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design solutions using models and simulations.
- Ask and evaluate questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-c)

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. (HS-PS4-d),(HS-ESS3-i)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.
- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. (HS-LS2-l)
- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-LS2-l)
- Design and conduct investigations and test design solutions in a

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting an Engineering Problem
- Design criteria and constraints, which typically reflect the needs of the end user of a technology or process, address such things as the product's or system's function (what job it will perform and how), its durability and limits on its size and cost. (HS-PS2-c),(HS-PS3-b),(HS-PS4-c),(HS-PS4-d),(HS-PS4-f),(HS-LS1-f),(HS-ESS1-f)
- Criteria and constraints 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. (HS-PS2-c),(HS-PS3-b),(HS-PS4-c),(HS-PS4-d),(HS-PS4-f),(HS-ESS3-f),(HS-ESS3-h)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges may also have manifestations in local communities. But, whatever the scale, the first things that engineers do is define the problem and specify the criteria and constraints for potential solutions. (HS-PS3-b),(HS-PS3-f),(HS-ESS3-b),(HS-ESS3-h),(HS-ESS3-i)

ETS1.B: Developing Possible Solutions
- To design something complicated one may need to break the problem into parts and attend to each part separately but must then bring the parts together to test the overall plan. (HS-PS4-f),(HS-ESS3-h)
- 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. (HS-PS2-c),(HS-PS3-b),(HS-LS2-j),(HS-ESS2-b),(HS-ESS3-f),(HS-ESS3-h)

Crosscutting Concepts

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-a),(HS-LS1-f),(HS-ESS2-h)
- Systems can be designed to cause a desired effect. (HS-PS2-c)
- Changes in systems may have various causes that may not have equal effects. (HS-PS2-a)

Systems and System Models
- Models (e.g., physical, mathematical and computer models) can be used to simulate systems and interactions within and between systems at different scales. (HS-ESS1-e)
- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-ESS3-i)

Energy and Matter
- Energy drives the cycling of matter within and between systems. (HS-ESS2-i)

Structure and Function
- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

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safe and ethical manner including considerations of environmental, social, and personal impacts. (HS-LS2-l)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-a),(HS-ESS2-i),(HS-ESS3-f)
- Evaluate the impact of new data on a working explanation of a proposed process or system. (HS-ESS3-f)

Using Mathematical and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations. (HS-ESS1-e)
- Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. (HS-ESS1-e)
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems. (HS-ESS3-e)
- Create a simple computational model or simulation of a designed device, process, or system. (HS-ESS3-e)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables. (HS-LS2-j)
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-PS3-b),(HS-LS1-f),(HS-LS2-j),(HS-ESS2-c)
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-LS1-f),(HS-ESS1-f),(HS-ESS2-b)
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (HS-ESS1-f)
- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS2-c),(HS-LS1-f),(HS-LS2-j)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Critique and evaluate competing arguments, models, and/or design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. (HS-LS3-c),(HS-ESS3-b)
- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-PS4-f)
- Make and defend a claim about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. (HS-PS4-f)
- Evaluate a claim for a design solution to a real-world problem based on scientific knowledge, empirical evidence, and logical arguments regarding all relevant factors (e.g. economic, societal, environmental, and ethical considerations). (HS-ESS3-b)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Testing should lead to improvements in the design through an iterative procedure. (HS-PS2-c),(HS-PS3-b),(HS-PS4-d) (HS-ESS3-f)
- Both physical models and computer models can be used in various ways to aid in the engineering design process. Physical models or prototypes are helpful in testing product ideas or the properties of different materials. (HS-PS2-a),(HS-PS4-d),(HS-ESS1-e),(HS-ESS1-f)
- Computer models are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify or describe a design problem; in 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. (HS-PS2-a),(HS-ESS1-e),(HS-ESS1-f)

ETS1.C: Optimizing the Design Solution

- The aim of engineering design is not simply to find a solution to a problem but to design the best solution under the given constraints and criteria. (HS-PS2-a),(HS-PS3-b),(HS-LS2-l),(HS-ESS2-c),(HS-ESS3-b),(HS-ESS3-f)
- When evaluating solutions, all relevant considerations, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts, should be included. (HS-LS3-c),(HS-ESS2-b),(HS-ESS2-i),(HS-ESS3-e),(HS-ESS3-f)
- Testing should lead to design improvements through an iterative process, and computer simulations are one useful way of running such tests. (HS-PS2-a),(HS-PS3-b)
- 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. (HS-PS4-f)
- The comparison of multiple designs can be aided by a trade-off matrix. (HS-PS4-f)

(HS-PS4-d),(HS-PS4-f),(HS-ESS2-c)

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS2-b),(HS-ESS3-f)
- Systems can be designed for greater or lesser stability. (HS-LS2-l),(HS-LS2-j)
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-f)
- Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS3-f)

Connection to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-PS3-f),(HS-LS3-c),(HS-ESS1-e),(HS-ESS1-f),(HS-ESS2-c)

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

- Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. (HS-PS3-b),(HS-PS3-f),(HS-PS4-c),(HS-PS4-d),(HS-PS4-f),(HS-ESS3-a),(HS-ESS3-e)
- Engineers continuously modify these systems to increase benefits while decreasing costs and risks. (HS-PS4-d),(HS-ESS3-b),(HS-ESS3-f)
- Widespread adoption of technological innovations often depends on market forces or other societal demands, but it may also be subject to evaluation by scientists and engineers and to eventual government regulation. (HS-PS3-b),(HS-PS3-f)
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-PS3-b),(HS-PS3-f),(HS-LS3-c),(HS-ESS2-b),(HS-ESS3-h),(HS-ESS3-d)

Connection to Nature of Science

Science is a Human Endeavor

- Scientific knowledge is a result of human endeavors, imagination, and creativity. (HS-ESS1-f)
- Individuals and teams from many nations and cultures have contributed to science and engineering advances. (HS-ESS1-f)
- Technological advances have influenced the progress of science and science has influenced advances in technology. (HS-LS3-c),(HS-ESS1-f)
- Science and engineering are influenced by society and society is influenced by science and engineering. (HS-LS3-c)

Science Addresses Questions About

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice, Disciplinary Core Idea, or Crosscutting Concept.

▪ Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system. (HS-PS3-f) --- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** ▪ Science knowledge is based on empirical evidence. (HS-ESS2-c) ▪ Science disciplines share common rules of evidence used to evaluate explanations about natural systems. (HS-ESS2-c) ▪ Science includes the process of coordinating patterns of evidence with current theory. (HS-ESS2-c) **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ▪ Theories and laws provide explanations in science, but theories do not with time become laws or facts. (HS-PS2-a) ▪ Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-a)		**the Natural and Material World** ▪ Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-b) ▪ Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-PS3-f),(HS-ESS3-b),(HS-ESS3-h) ▪ Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-PS3-f),(HS-ESS3-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation to DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections: [Note: these connections will be made available soon.]
ELA/Literacy –
Mathematics –

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