Science and Technology/Engineering Learning Standards

Overview of the Standards

The Massachusetts standards are an adaptation of the Next Generation Science Standards (NGSS) based on the *Framework for K–12 Science Education* (NRC, 2012). This is done so educators and districts can benefit from commonality across states, including use of NGSS-aligned resources created elsewhere. Common features include:

- Integration of science and engineering practices.

- Grade-by-grade standards for elementary school that include all STE disciplines.

- Application of science in engineering contexts.

While the Massachusetts STE standards have much in common with NGSS, public input from across the Commonwealth during the development of the standards identified several needed adaptations for Massachusetts:

- Include technology/engineering as a discipline equivalent to traditional sciences.

- Include only two dimensions (disciplinary core ideas and science and engineering practices) in the standards, while encouraging the inclusion of crosscutting concepts and the nature of science in the curriculum.

- Balance broad concepts with specificity to inform consistent interpretation.

- Maintain the Massachusetts model of introductory high school course options.

Structural Features of the Standards

The STE standards are presented using a consistent structure:
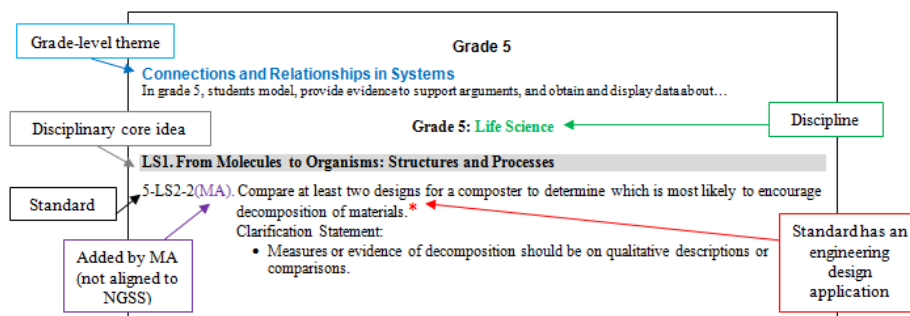
The pre-K–8 standards are presented by grade, with each grade focused on a grade-level theme that links the standards and all four STE disciplines (see Appendix V). High school standards are provided for five common introductory-level courses. Standards are organized by disciplinary core ideas, consistently referenced throughout the grades. For standards that are not aligned to NGSS (i.e., standards added by Massachusetts) an "(MA)" has been added to the label. Asterisks (*) designate standards that have an engineering design application.

Labeling/Coding of the Standards

The Massachusetts STE standards are labeled using the NGSS system, as shown here:
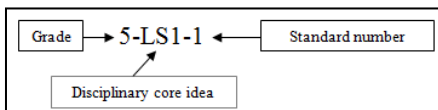
The first component of each label indicates the grade (pre-K to grade 8) and/or span (middle or high school). The next component specifies the discipline and core idea. Finally, the number at the end of each label indicates the particular standard within the related set.

Maintaining the labeling system from NGSS is intended to allow Massachusetts' educators access to curriculum and instruction resources developed across the country. This occasionally results in standards that appear to be out of sequence or skip a number (because some NGSS standards are not included in the Massachusetts standards), but the benefits of consistency with NGSS outweigh those of renumbering. *Note that the order in which the standards are listed does not imply or define an intended instructional sequence.*

Components of the Standards

Many standards include *clarification statements* (which supply examples or additional clarification to the standards) and *state assessment boundary statements* (which are meant to specify limits to state assessment). *Note that these are not intended to limit or constrain curriculum or classroom instruction: educators are welcome to teach and assess additional concepts, practices, and vocabulary that are not included in the standards.*

Relationship of Standards to Curriculum and Instruction

The standards are outcomes, or goals, that reflect what a student should know and be able to do. They do not dictate a manner or methods of teaching. The standards are written in a way that expresses the concept and skills to be achieved and demonstrated by students, but leaves curricular and instructional decisions to districts, schools, and teachers. The standards are not a set of instructional activities or assessment tasks. They are statements of what students should be able to do *as a result of* instruction.

In particular, it is important to note that the scientific and engineering practices are not teaching strategies—they are important learning goals in their own right; they are skills to be learned as a result of instruction. As the standards are performances meant to be accomplished at the conclusion of instruction, quality instruction should engage students in multiple practices throughout instruction. Students cannot comprehend scientific practices, or fully appreciate the nature of scientific knowledge itself, without learning the science and engineering practices. This *Framework* uses the term "practices" instead of terms such as "inquiry" or "skills" to emphasize that the practices are outcomes to be learned, not a method of instruction.

It is also important to note that the standards identify the most essential material for students to know and do. They are not an exhaustive list of all that could be included in a student's science education; students should not be prevented from going beyond them where appropriate. Teachers have the flexibility to arrange the standards in any order within a grade level and add areas of study to suit the needs of their students and science programs. Including various applications of science, such as biotechnology, clean energy, medicine, forensics, agriculture, or robotics, would nicely facilitate student interest and demonstrate how the standards are applied in real-world contexts (see Appendix IX).

References

National Research Council (NRC). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: The National Academies Press.

Use of Selected Terms

This section clarifies the intended use of certain terms in the standards.

Engineering Design

- *Design problem:* An articulation of a problem to be solved or a thing to be improved that addresses a personal, communal, or societal need. Engaging in or addressing a design problem results in a product (a physical thing or a process).

Scale

- *Local:* Describes an area relevant to what is being studied, generally a local community or small region (e.g., an area of a state). Does not have to be near where the student lives, although that can be the area under study. A local area can also be, for example, a place in Costa Rica if the topic of study is a rain forest, or a place in the Arctic if that is being studied.

- *Regional:* Generally refers to a statewide or multistate perspective relative to what is being studied or, if on another continent, approximately a country or small set of countries that constitute a regional scope.

Material Properties

Different properties of materials are specified and used throughout the standards. The table below shows the grade span at which each property is introduced. Once introduced at one grade level, the property may be used, referred to, or expected in any later grade. A check mark (✓) indicates that the property is specified again in the later grade span.

Pre-K–2	3–5	6–8	HS
Absorbency			
Color	✓	✓	
Flexibility		✓	
Hardness	✓	✓	✓
Texture			
	Electrical conductivity	✓	
	Response to magnetic forces		
	Reflectivity		
	Solubility	✓	✓
	Thermal conductivity	✓	✓
		Boiling point	✓
		Density	✓
		Ductility	
		Flammability	
		Melting point	✓
			Elasticity
			Plasticity
			Reactivity
			Resistance to force
			Surface tension
			Vapor pressure

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Grades Pre-K–2: Overview of Science and Engineering Practices

The development of science and engineering practices begins very early, even as babies and young children inquire about and explore how the world works. Formal education should advance students' development of the skills necessary to engage in scientific inquiry and engineering design. These are the skills that provide the foundation for the scientific and technical reasoning that is so critical to success in civic life, postsecondary education, and careers. Inclusion of science and engineering practices in standards only speaks to the types of performances students should be able to demonstrate at the end of instruction at a particular grade; the standards do not limit what educators and students should or can be engaged in through a well-rounded curriculum.

Pre-K through grade 2 standards integrate all eight science and engineering practices. Pre-K standards ask students to demonstrate an ability to ask questions, set up simple investigations, analyze evidence, observations, and data for patterns, and use evidence to explain or develop ideas about how phenomena work. Kindergarten standards call for students to show further development of investigation and communication skills, as well as application of science concepts to designing solutions to problems, and to now use information obtained from text and media sources. Grade 1 standards call for students to continue developing investigation skills, including their ability to pose scientific questions as well as their ability to analyze observations and data and to effectively use informational sources. Grade 1 standards also call for students to demonstrate their ability to craft scientific explanations using evidence from a variety of sources. Grade 2 standards call for students to use models in a scientific context and further their skills in a number of the practices, including investigations, data analysis, designing solutions, argumentation, and use of informational sources.

Some examples of specific skills students should develop in these grades:

1. Raise questions about how different types of environments provide homes for living things; ask and/or identify questions that can be answered by an investigation.

2. Use a model to compare how plants and animals depend on their surroundings; develop and/or use a model to represent amounts, relationships, and/or patterns in the natural world; distinguish between a model and the actual object and/or process the model represents.

3. Conduct an investigation of light and shadows; plan and conduct an investigation collaboratively to produce data to answer a question; make observations and/or relative measurements to collect data that can be used to make comparisons.

4. Analyze data to identify relationships among seasonal patterns of change; use observations to describe patterns and/or relationships in the natural world and to answer scientific questions.

5. Decide when to use qualitative vs. quantitative information; use counting and numbers to describe patterns in the natural world.

6. Use information from observations to construct an evidence-based account of nature.

7. Construct an argument with evidence for how plants and animals can change the environment; distinguish between opinions and evidence in one's own explanations; listen actively to others to indicate agreement or disagreement based on evidence.

8. Obtain information to compare ways that parents and their offspring behave to survive; obtain information using various texts, text features, or other media to answer a question.

While presented as distinct skill sets, the eight practices intentionally overlap and interconnect. Skills such as those outlined above should be reflected in curricula and instruction that engage students in an integrated use of the practices. See the Science and Engineering Practices Progression Matrix (Appendix I) for more information, including particular skills for students in grades pre-K–2.

Pre-Kindergarten

The World Around Me

Pre-K students focus on experiencing and making observations of the world around them. They are beginning to learn about their own environment as they observe plants and animals, the Moon and the Sun, and the daily weather. They experience their world through their senses and body parts and begin to recognize that animals also use their senses and body parts to meet their basic needs. They investigate pitch and volume, shadow and light, liquids and solids, and how things move. They sort materials by simple observable properties such as texture and color. They share their understanding of these concepts through discussion as they develop their language and quantitative skills. Pre-K students build awareness of the wide variety of natural phenomena and processes in the world around them.

Pre-K: Earth and Space Sciences

ESS1. Earth's Place in the Universe

PreK-ESS1-1(MA). Demonstrate awareness that the Moon can be seen in the daytime and at night, and of the different apparent shapes of the Moon over a month.
    Clarification Statement:
        • The names of moon phases or sequencing of moon phases is not expected.
PreK-ESS1-2(MA). Observe and use evidence to describe that the Sun is in different places in the sky during the day.

ESS2. Earth's Systems

PreK-ESS2-1(MA). Raise questions and engage in discussions about how different types of local environments (including water) provide homes for different kinds of living things.
PreK-ESS2-2(MA). Observe and classify non-living materials, natural and human made, in the local environment.
PreK-ESS2-3(MA). Explore and describe different places water is found in the local environment.
PreK-ESS2-4(MA). Use simple instruments to collect and record data on elements of daily weather, including sun or clouds, wind, snow or rain, and higher or lower temperature.
PreK-ESS2-5(MA). Describe how local weather changes from day to day and over the seasons and recognize patterns in those changes.
    Clarification Statement:
        • Descriptions of the weather can include sunny, cloudy, rainy, warm, windy, and snowy.
PreK-ESS2-6(MA). Provide examples of the impact of weather on living things.
    Clarification Statement:
        • Make connections between the weather and what they wear and can do and the weather and the needs of plants and animals for water and shelter.

ESS3. Earth and Human Activity

PreK-ESS3-1(MA). Engage in discussion and raise questions using examples about local resources (including soil and water) humans use to meet their needs.
PreK-ESS3-2(MA). Observe and discuss the impact of people's activities on the local environment.

Pre-K: Life Science

LS1. From Molecules to Organisms: Structures and Processes

PreK-LS1-1(MA). Compare, using descriptions and drawings, the external body parts of animals (including humans) and plants and explain functions of some of the observable body parts.
Clarification Statement:
- Examples can include comparison of humans and horses: humans have two legs and horses four, but both use legs to move.

PreK-LS1-2(MA). Explain that most animals have five senses they use to gather information about the world around them.

PreK-LS1-3(MA). Use their five senses in their exploration and play to gather information.

LS2. Ecosystems: Interactions, Energy, and Dynamics

PreK-LS2-1(MA). Use evidence from animals and plants to define several characteristics of living things that distinguish them from non-living things.

PreK-LS2-2(MA). Using evidence from the local environment, explain how familiar plants and animals meet their needs where they live.
Clarification Statements:
- Basic needs include water, food, air, shelter, and, for most plants, light.
- Examples of evidence can include squirrels gathering nuts for the winter and plants growing in the presence of sun and water.
- The local environment includes the area around the student's school, home, or adjacent community.

PreK-LS2-3(MA). Give examples from the local environment of how animals and plants are dependent on one another to meet their basic needs.

LS3. Variation of Traits

PreK-LS3-1(MA). Use observations to explain that young plants and animals are like but not exactly like their parents.
Clarification Statement:
- Examples of observations include puppies that look similar but not exactly the same as their parents.

PreK-LS3-2(MA). Use observations to recognize differences and similarities among themselves and their friends.

Pre-K: Physical Sciences

PS1. Matter and Its Interactions

PreK-PS1-1(MA). Raise questions and investigate the differences between liquids and solids and develop awareness that a liquid can become a solid and vice versa.

PreK-PS1-2(MA). Investigate natural and human-made objects to describe, compare, sort, and classify objects based on observable physical characteristics, uses, and whether something is manufactured or occurs in nature.

PreK-PS1-3(MA). Differentiate between the properties of an object and those of the material of which it is made.

PreK-PS1-4(MA). Recognize through investigation that physical objects and materials can change under different circumstances.
Clarification Statement:
- Changes include building up or breaking apart, mixing, dissolving, and changing state.

PS2. Motion and Stability: Forces and Interactions

PreK-PS2-1(MA). Using evidence, discuss ideas about what is making something move the way it does and how some movements can be controlled.

PreK-PS2-2(MA). Through experience, develop awareness of factors that influence whether things stand or fall.
   Clarification Statement:
   - Examples of factors in children's construction play include using a broad foundation when building, considering the strength of materials, and using balanced weight distribution in a block building.

PS4. Waves and Their Applications in Technologies for Information Transfer

PreK-PS4-1(MA). Investigate sounds made by different objects and materials and discuss explanations about what is causing the sounds. Through play and investigations, identify ways to manipulate different objects and materials that make sound to change volume and pitch.

PreK-PS4-2(MA). Connect daily experiences and investigations to demonstrate the relationships between the size and shape of shadows, the objects creating the shadow, and the light source.

Kindergarten

Reasons for Change

In kindergarten, students build on early experiences observing the world around them as they continue to make observations that are more quantitative in nature and help them identify why some changes occur. Students begin to learn to use these observations as evidence to support a claim through growing language skills. They learn that all animals and plants need food, water, and air to grow and thrive and that the fundamental difference between plants and animals is a plant's ability to make its own food. Students build their quantitative knowledge of temperature in relation to the weather and its effect on different kinds of materials. They observe that the amount of sunlight shining on a surface causes a temperature change and they design a structure to reduce the warming effects of sunlight. They investigate motions of objects by changing the strength and direction of pushes and pulls. They provide examples of plants and animals that can change their environment through their interactions with it. In kindergarten science, students begin to identify reasons for changes in some common phenomena.

Kindergarten: Earth and Space Sciences

ESS2. Earth's Systems

K-ESS2-1. Use and share quantitative observations of local weather conditions to describe patterns over time.
  Clarification Statements:
  * Examples of quantitative observations could include numbers of sunny, windy, and rainy days in a month, and relative temperature.
  * Quantitative observations should be limited to whole numbers.
K-ESS2-2. Construct an argument supported by evidence for how plants and animals (including humans) can change the environment.
  Clarification Statement:
  * Examples of plants and animals changing their environment could include a squirrel digging holes in the ground and tree roots that break concrete.

ESS3. Earth and Human Activity

K-ESS3-2. Obtain and use information about weather forecasting to prepare for, and respond to, different types of local weather.
K-ESS3-3. Communicate solutions to reduce the amount of natural resources an individual uses.*
  Clarification Statement:
  * Examples of solutions could include reusing paper to reduce the number of trees cut down and recycling cans and bottles to reduce the amount of plastic or metal used.

[K-ESS3-1 from NGSS is not included.]

Kindergarten: Life Science

LS1. From Molecules to Organisms: Structures and Processes

K-LS1-1. Observe and communicate that animals (including humans) and plants need food, water, and air to survive. Animals get food from plants or other animals. Plants make their own food and need light to live and grow.
K-LS1-2(MA). Recognize that all plants and animals grow and change over time.

Kindergarten: Physical Science

PS1. Matter and Its Interactions

K-PS1-1(MA). Investigate and communicate the idea that different kinds of materials can be solid or liquid depending on temperature.
Clarification Statements:
- Materials chosen must exhibit solid and liquid states in a reasonable temperature range for kindergarten students (e.g., 0–80°F), such as water, crayons, or glue sticks.
- Only a qualitative description of temperature, such as hot, warm, and cool, is expected.

PS2. Motion and Stability: Forces and interactions

K-PS2-1. Compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.
Clarification Statements:
- Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.
- Comparisons should be on different relative strengths or different directions, not both at the same time.
- Non-contact pushes or pulls such as those produced by magnets are not expected.

[K-PS2-2 from NGSS is not included.]

PS3. Energy

K-PS3-1. Make observations to determine that sunlight warms materials on Earth's surface.
Clarification Statements:
- Examples of materials on Earth's surface could include sand, soil, rocks, and water.
- Measures of temperature should be limited to relative measures such as warmer/cooler.

K-PS3-2. Use tools and materials to design and build a model of a structure that will reduce the warming effect of sunlight on an area.*

Grade 1

Describing Patterns

In grade 1, students have more fluency with language, number sense, and inquiry skills. This allows them to describe patterns of motion between the Sun, Moon, and stars in relation to the Earth. From this understanding they can identify seasonal patterns from sunrise and sunset data that will allow them to predict future patterns. Building from their experiences in pre-K and kindergarten observing and describing daily weather, they can now examine seasonal data on temperature and rainfall to describe patterns over time. Grade 1 students investigate sound and light through various materials. They describe patterns in how light passes through and sounds differ from different types of materials and use this to design and build a device to send a signal. Students compare the ways different animals and plants use their body parts and senses to do the things they need to do to grow and survive, including typical ways parents keep their young safe so they will survive to adulthood. They notice that though there are differences between plants or animals of the same type, the similarities of behavior and appearance are what allow us to identify them as belonging to a group. Grade 1 students begin to understand the power of patterns to predict future events in the natural and designed world.

Grade 1: Earth and Space Sciences

ESS1. Earth's Place in the Universe

1-ESS1-1. Use observations of the Sun, Moon, and stars to describe that each appears to rise in one part of the sky, appears to move across the sky, and appears to set.

1-ESS1-2. Analyze provided data to identify relationships among seasonal patterns of change, including relative sunrise and sunset time changes, seasonal temperature and rainfall or snowfall patterns, and seasonal changes to the environment.
Clarification Statement:
- Examples of seasonal changes to the environment can include foliage changes, bird migration, and differences in amount of insect activity.

Grade 1: Life Science

LS1. From Molecules to Organisms: Structures and Processes

1-LS1-1. Use evidence to explain that (a) different animals use their body parts and senses 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, and (b) plants have roots, stems, leaves, flowers, and fruits that are used to take in water, air, and other nutrients, and produce food for the plant.
Clarification Statement:
- Descriptions are not expected to include mechanisms such as the process of photosynthesis.

1-LS1-2. Obtain information to compare ways in which the behavior of different animal parents and their offspring help the offspring to survive.
Clarification Statement:
- Examples of behaviors could include the signals that offspring make (such as crying, cheeping, and other vocalizations) and the responses of the parents (such as feeding, comforting, and protecting the offspring).

LS3. Heredity: Inheritance and Variation of Traits

1-LS3-1. Use information from observations (first-hand and from media) to identify similarities and differences among individual plants or animals of the same kind.
Clarification Statements:
- Examples of observations could include that leaves from the same kind of plant are the same shape but can differ in size.
- Inheritance, animals that undergo metamorphosis, or hybrids are not expected.

Grade 1: Physical Science

PS4. Waves and Their Applications in Technologies for Information Transfer

1-PS4-1. Demonstrate that vibrating materials can make sound and that sound can make materials vibrate.
Clarification Statements:
- Examples of vibrating materials that make sound could include tuning forks, a stretched string or rubber band, and a drum head.
- Examples of how sound can make materials vibrate could include holding a piece of paper near a speaker making sound and holding an object near a vibrating tuning fork.

1-PS4-3. Conduct an investigation to determine the effect of placing materials that allow light to pass through them, allow only some light through them, block all the light, or redirect light when put in the path of a beam of light.
Clarification Statements:
- Effects can include some or all light passing through, creation of a shadow, and redirecting light.
- Quantitative measures are not expected.

1-PS4-4. Use tools and materials to design and build a device that uses light or sound to send a signal over a distance.*
Clarification Statements:
- Examples of devices could include a light source to send signals, paper cup and string "telephones," and a pattern of drum beats.
- Technological details for how communication devices work are not expected.

[1-PS4-2 from NGSS is not included.]

Grade 1: Technology/Engineering

ETS1. Engineering Design

1.K-2-ETS1-1. Ask questions, make observations, and gather information about a situation people want to change that can be solved by developing or improving an object or tool.*

1.K-2-ETS1-2. Generate multiple solutions to a design problem and make a drawing (plan) to represent one or more of the solutions.*

[K-2-ETS1-3 is found in grade 2.]

Grade 2

Wholes and Parts

As students grow in their ability to speak, read, write, and reason mathematically, they also grow in their ability to grapple with larger systems and the parts that make them up. In grade 2, students start to look beyond the structures of individual plants and animals to looking at the environment in which the plants and animals live as a provider of the food, water, and shelter that the organisms need. They learn that water is found everywhere on Earth and takes different forms and shapes. They map landforms and bodies of water and observe that flowing water and wind shapes these landforms. Grade 2 students use their observation skills gained in earlier grades to classify materials based on similar properties and functions. They gain experience testing different materials to collect and then analyze data for the purpose of determining which materials are the best for a specific function. They construct large objects from smaller pieces and, conversely, learn that when materials are cut into the smallest possible pieces, they still exist as the same material that has weight. These investigations of how parts relate to the whole provide a key basis for understanding systems in later grades.

Grade 2: Earth and Space Sciences

ESS1. Earth's Place in the Universe

[2-ESS1-1 from NGSS is not included.]

ESS2. Earth's Systems

2-ESS2-1. Investigate and compare the effectiveness of multiple solutions designed to slow or prevent wind or water from changing the shape of the land.*
　　　　Clarification Statements:
- Solutions to be compared could include different designs of dikes and windbreaks to hold back wind and water, and different designs for using shrubs, grass, and trees to hold back the land.
- Solutions can be generated or provided.

2-ESS2-2. Map the shapes and types of landforms and bodies of water in an area.
　　　　Clarification Statements:
- Examples of types of landforms can include hills, valleys, river banks, and dunes.
- Examples of water bodies can include streams, ponds, bays, and rivers.
- Quantitative scaling in models or contour mapping is not expected.

2-ESS2-3. Use examples obtained from informational sources to explain that water is found in the ocean, rivers and streams, lakes and ponds, and may be solid or liquid.

2-ESS2-4(MA). Observe how blowing wind and flowing water can move Earth materials from one place to another and change the shape of a landform.
　　　　Clarification Statement:
- Examples of types of landforms can include hills, valleys, river banks, and dunes.

Grade 2: Life Science

LS2. Ecosystems: Interactions, Energy, and Dynamics

2-LS2-3(MA). Develop and use models to compare how plants and animals depend on their surroundings and other living things to meet their needs in the places they live.
Clarification Statement:
- Animals need food, water, air, shelter, and favorable temperature; plants need sufficient light, water, minerals, favorable temperature, and animals or other mechanisms to disperse seeds.

[2-LS2-1 is included in other standards, including K-LS1-1 and 2-LS2-3(MA). 2-LS2-2 from NGSS is not included.]

LS4. Biological Evolution: Unity and Diversity

2-LS4-1. Use texts, media, or local environments to observe and compare (a) different kinds of living things in an area, and (b) differences in the kinds of living things living in different types of areas.
Clarification Statements:
- Examples of areas to compare can include temperate forest, desert, tropical rain forest, grassland, arctic, and aquatic.
- Specific animal and plant names in specific areas are not expected.

Grade 2: Physical Science

PS1. Matter and Its Interactions

2-PS1-1. Describe and classify different kinds of materials by observable properties of color, flexibility, hardness, texture, and absorbency.
2-PS1-2. Test different materials and analyze the data obtained to determine which materials have the properties that are best suited for an intended purpose.*
Clarification Statements:
- Examples of properties could include, color, flexibility, hardness, texture, and absorbency.
- Data should focus on qualitative and relative observations.
2-PS1-3. Analyze a variety of evidence to conclude that when a chunk of material is cut or broken into pieces, each piece is still the same material and, however small each piece is, has weight. Show that the material properties of a small set of pieces do not change when the pieces are used to build larger objects.
Clarification Statements:
- Materials should be pure substances or microscopic mixtures that appear contiguous at observable scales.
- Examples of pieces could include blocks, building bricks, and other assorted small objects.
2-PS1-4. Construct an argument with evidence that some changes to materials caused by heating or cooling can be reversed and some cannot.
Clarification Statements:
- Examples of reversible changes could include materials such as water and butter at different temperatures.
- Examples of irreversible changes could include cooking an egg, freezing a plant leaf, and burning paper.

PS3. Energy

2-PS3-1(MA). Design and conduct an experiment to show the effects of friction on the relative temperature and speed of objects that rub against each other.
Clarification Statements:
- Examples could include an object sliding on rough vs. smooth surfaces.
- Observations of temperature and speed should be qualitative.

Grade 2: Technology/Engineering

ETS1. Engineering Design

2.K-2-ETS1-3. Analyze data from tests of two objects designed to solve the same design problem to compare the strengths and weaknesses of how each object performs.*
Clarification Statements:
- Data can include observations and be either qualitative or quantitative.
- Examples can include how different objects insulate cold water or how different types of grocery bags perform.

[K-2-ETS1-1 and K-2-ETS1-2 are found in grade 1.]

Grades 3–5: Overview of Science and Engineering Practices

Upper elementary is a critical time to engage students in the science and engineering practices. Students form key identities with, or against, science and engineering as they leave elementary school that can shape their relationship to science in later education, and even postsecondary and career choices later in life. Students must be given opportunities to develop the skills necessary for a meaningful progression of development in order to engage in the scientific and technical reasoning so critical to success in civic life, postsecondary education, and careers. Inclusion of science and engineering practices in standards only speaks to the types of performance students should be able to demonstrate at the end of instruction at a particular grade; the standards do not limit what educators and students should or can be engaged in through a well-rounded curriculum.

Standards for grades 3 through 5 integrate all eight science and engineering practices. Some examples of specific skills students should develop in these grades include:

1. Ask questions and predict outcomes about the changes in energy when objects collide; distinguish between scientific (testable) and non-scientific (non-testable) questions; define a simple design problem, including criteria for success and constraints on materials or time.

2. Use graphical representations to show differences in organisms' life cycles; develop a model of a wave to communicate wave features; use a particulate model of matter to explain phase changes; identify limitations of models; use a model to test cause and effect relationships.

3. Conduct an investigation to determine the nature of forces between magnets; make observations and collect data about the effects of mechanical weathering; conduct an experiment on mixing of substances; evaluate appropriate methods for collecting data; make predictions about what would happen if a variable changes.

4. Use graphs and tables of weather data to describe and predict typical weather during a season; analyze and interpret maps of Earth's physical features; use data to evaluate and refine design solutions.

5. Graph and describe the amounts and percentages of fresh and salt water in various reservoirs; measure and graph weights of substances before and after a chemical reaction.

6. Use evidence to explain how variations among individuals can provide advantages in survival and reproduction; provide evidence to explain the effect of multiple forces on the motion of an object; test and refine a simple system designed to filter impurities out of water.

7. Construct an argument that animals and plants have internal and external structures that support their survival, growth, behavior, and reproduction; distinguish among facts, reasoned judgment based on data, and speculation in an argument.

8. Obtain and summarize information about the climate of different regions; gather information on possible solutions to a given design problem; obtain information about renewable and nonrenewable energy sources.

While presented as distinct skill sets, the eight practices intentionally overlap and interconnect. Skills such as those outlined above should be reflected in curricula and instruction that engage students in an integrated use of the practices. See the Science and Engineering Practices Progression Matrix (Appendix I) for more information, including particular skills for students in grades 3–5.

Grade 3

Human Interactions

In grade 3, students develop and sharpen their skills at obtaining, recording and charting, and analyzing data in order to study their environment. They use these practices to study the interactions between humans and earth systems, humans and the environment, and humans and the designed world. They learn that these entities not only interact but influence behaviors, reactions, and traits of organisms. Grade 3 students analyze weather patterns and consider humans' influence and opportunity to impact weather-related events. In life science they study the interactions between and influence of the environment and human traits and characteristics. They use the engineering design process to identify a problem and design solutions that enhance humans' interactions with their surroundings and to meet their needs. Students consider the interactions and consequent reactions between objects and forces, including forces that are balanced or not. Students reason and provide evidence to support arguments for the influence of humans on nature and nature on human experience.

Grade 3: Earth and Space Sciences

ESS2. Earth's Systems

3-ESS2-1. Use graphs and tables of local weather data to describe and predict typical weather during a particular season in an area.
  Clarification Statements:
  - Examples of weather data could include temperature, amount and type of precipitation (e.g., rain, snow), wind direction, and wind speed.
  - Graphical displays should focus on pictographs and bar graphs.
3-ESS2-2. Obtain and summarize information about the climate of different regions of the world to illustrate that typical weather conditions over a year vary by region.
  Clarification Statement:
  - Examples of information can include climate data (average temperature, average precipitation, average wind speed) or comparative descriptions of seasonal weather for different regions.
  State Assessment Boundary:
  - An understanding of climate change is not expected in state assessment.

ESS3. Earth and Human Activity

3-ESS3-1. Evaluate the merit of a design solution that reduces the damage caused by weather.*
  Clarification Statement:
  - Examples of design solutions to reduce weather-related damage could include a barrier to prevent flooding, a wind-resistant roof, and a lightning rod.

Grade 3: Life Science

LS1. From Molecules to Organisms: Structures and Processes

3-LS1-1. Use simple graphical representations to show that different types of organisms have unique and diverse life cycles. Describe that all organisms have birth, growth, reproduction, and death in common but there are a variety of ways in which these happen.
Clarification Statements:
- Examples can include different ways plants and animals begin (e.g., sprout from a seed, born from an egg), grow (e.g., increase in size and weight, produce a new part), reproduce (e.g., develop seeds, root runners, mate and lay eggs that hatch), and die (e.g., length of life).
- Plant life cycles should focus on those of flowering plants.
- Describing variation in organism life cycles should focus on comparisons of the general stages of each, not specifics.
State Assessment Boundary:
- Detailed descriptions of any one organism's cycle, the differences of "complete metamorphosis" and "incomplete metamorphosis," or details of human reproduction are not expected in state assessment.

LS2. Ecosystems: Interactions, Energy, and Dynamics

[3-LS2-1 from NGSS is not included.]

LS3. Heredity: Inheritance and Variation of Traits

3-LS3-1. Provide evidence, including through the analysis of data, that plants and animals have traits inherited from parents and that variation of these traits exist in a group of similar organisms.
Clarification Statements:
- Examples of inherited traits that vary can include the color of fur, shape of leaves, length of legs, and size of flowers.
- Focus should be on non-human examples.
State Assessment Boundary:
- Genetic mechanisms of inheritance or prediction of traits are not expected in state assessment.
3-LS3-2. Distinguish between inherited characteristics and those characteristics that result from a direct interaction with the environment. Give examples of characteristics of living organisms that are influenced by both inheritance and the environment.
Clarification Statements:
- Examples of the environment affecting a characteristic could include normally tall plants stunted because they were grown with insufficient water or light, a lizard missing a tail due to a predator, and a pet dog becoming overweight because it is given too much food and little exercise.
- Focus should be on non-human examples.

LS4. Biological Evolution: Unity and Diversity

3-LS4-1. Use fossils to describe types of organisms and their environments that existed long ago and compare those to living organisms and their environments. Recognize that most kinds of plants and animals that once lived on Earth are no longer found anywhere.
Clarification Statement:
- Comparisons should focus on physical or observable features.

- Identification of specific fossils or specific present-day plants and animals, dynamic processes, or genetics are not expected in state assessment.

3-LS4-2. Use evidence to construct an explanation for how the variations in characteristics among individuals within the same species may provide advantages to these individuals in their survival and reproduction.

Clarification Statements:

- Examples can include rose bushes of the same species, one with slightly longer thorns than the other which may prevent its predation by deer, and color variation within a species that may provide advantages so one organism may be more likely to survive and therefore more likely to produce offspring.
- Examples of evidence could include needs and characteristics of the organisms and habitats involved.

3-LS4-3. Construct an argument with evidence that in a particular environment some organisms can survive well, some survive less well, and some cannot survive.

Clarification Statement:

- Examples of evidence could include needs and characteristics of the different organisms (species) and habitats involved.

3-LS4-4. Analyze and interpret given data about changes in a habitat and describe how the changes may affect the ability of organisms that live in that habitat to survive and reproduce.

Clarification Statements:

- Changes should include changes to landforms, distribution of water, climate, and availability of resources.
- Changes in the habitat could range in time from a season to a decade.
- While it is understood that ecological changes are complex, the focus should be on a single change to the habitat.

3-LS4-5(MA). Provide evidence to support a claim that the survival of a population is dependent upon reproduction.

State Assessment Boundary:

- Details of reproduction are not expected in state assessment.

Grade 3: Physical Science

PS2. Motion and Stability: Forces and Interactions

3-PS2-1. Provide evidence to explain the effect of multiple forces, including friction, on an object. Include balanced forces that do not change the motion of the object and unbalanced forces that do change the motion of the object.

Clarification Statements:

- Descriptions of force magnitude should be qualitative and relative.
- Force due to gravity is appropriate but only as a force that pulls objects down.

State Assessment Boundaries:

- Quantitative force magnitude is not expected in state assessment.
- State assessment will be limited to one variable at a time: number, size, or direction of forces.

3-PS2-3. Conduct an investigation to determine the nature of the forces between two magnets based on their orientations and distance relative to each other.

Clarification Statement:

- Focus should be on forces produced by magnetic objects that are easily manipulated.

3-PS2-4. Define a simple design problem that can be solved by using interactions between magnets.*
Clarification Statement:
- Examples of problems could include constructing a latch to keep a door shut and creating a device to keep two moving objects from touching each other.

[3-PS2-2 from NGSS is not included.]

Grade 3: Technology/Engineering

ETS1. Engineering Design

3.3-5-ETS1-1. Define a simple design problem that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost that a potential solution must meet.*

3.3-5-ETS1-2. Generate several possible solutions to a given design problem. Compare each solution based on how well each is likely to meet the criteria and constraints of the design problem.*
Clarification Statement:
- Examples of design problems can include adapting a switch on a toy for children who have a motor coordination disability, designing a way to clear or collect debris or trash from a storm drain, or creating safe moveable playground equipment for a new recess game.

3.3-5-ETS1-4(MA). Gather information using various informational resources on possible solutions to a design problem. Present different representations of a design solution.*
Clarification Statements:
- Examples of informational resources can include books, videos, and websites.
- Examples of representations can include graphic organizers, sketches, models, and prototypes.

[3-5-ETS1-3 and 3-5-ETS1-5(MA) are found in grade 4.]

Grade 4

Matter and Energy

In grade 4, students observe and interpret patterns related to the transfer of matter and energy on Earth, in physical interactions, and in organisms. Students learn about energy—its motion, transfer, and conversion—in different physical contexts. Grade 4 students interpret patterns of change over time as related to the deposition and erosion in landscape formation. They study today's landscapes to provide evidence for past processes. Students learn that animals' internal and external structures support life, growth, behavior, and reproduction. They work through the engineering design process, focusing on developing solutions by building, testing, and redesigning prototypes to fit a specific purpose. Each domain relates to the use of matter and energy over time and for specific purposes.

Grade 4: Earth and Space Sciences

ESS1. Earth's Place in the Universe

4-ESS1-1. Use evidence from a given landscape that includes simple landforms and rock layers to support a claim about the role of erosion or deposition in the formation of the landscape over long periods of time.
Clarification Statements:
- Examples of evidence and claims could include rock layers with shell fossils above rock layers with plant fossils and no shells, indicating a change from deposition on land to deposition in water over time; and a canyon with rock layers in the walls and a river in the bottom, indicating that a river eroded the rock over time.
- Examples of simple landforms can include valleys, hills, mountains, plains, and canyons.
- Focus should be on relative time.
State Assessment Boundary:
- Specific details of the mechanisms of rock formation or specific rock formations and layers are not expected in state assessment.

ESS2. Earth's Systems

4-ESS2-1. Make observations and collect data to provide evidence that rocks, soils, and sediments are broken into smaller pieces through mechanical weathering and moved around through erosion.
Clarification Statements:
- Mechanical weathering processes can include frost wedging, abrasion, and tree root wedging.
- Erosion can include movement by blowing wind, flowing water, and moving ice.
State Assessment Boundary:
- Chemical processes are not expected in state assessment.

4-ESS2-2. Analyze and interpret maps of Earth's mountain ranges, deep ocean trenches, volcanoes, and earthquake epicenters to describe patterns of these features and their locations relative to boundaries between continents and oceans.

ESS3. Earth and Human Activity

4-ESS3-1. Obtain information to describe that energy and fuels humans use are derived from natural resources and that some energy and fuel sources are renewable and some are not.
Clarification Statements:

- Examples of renewable energy resources could include wind energy, water behind dams, tides, and sunlight.
- Non-renewable energy resources are fossil fuels and nuclear materials.

4-ESS3-2. Evaluate different solutions to reduce the impacts of a natural event such as an earthquake, blizzard, or flood on humans.*

Clarification Statement:
- Examples of solutions could include an earthquake-resistant building or a constructed wetland to mitigate flooding.

Grade 4: Life Science

LS1. From Molecules to Organisms: Structures and Processes

4-LS1-1. Construct an argument that animals and plants have internal and external structures that support their survival, growth, behavior, and reproduction.

Clarification Statements:
- Animal structures can include legs, wings, fins, feathers, trunks, claws, horns, antennae, eyes, ears, nose, heart, stomach, lung, brain, and skin.
- Plant structures can include leaves, roots, stems, bark, branches, flowers, fruit, and seeds.

State Assessment Boundary:
- State assessment will be limited to macroscopic structures.

[4-LS1-2 from NGSS is not included.]

Grade 4: Physical Science

PS3. Energy

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

State Assessment Boundaries:
- State assessment will be limited to analysis of kinetic energy.
- Accounting for mass, quantitative measures of changes in the speed of an object, or any precise or quantitative definition of energy is not expected in state assessment.

4-PS3-2. Make observations to show that energy can be transferred from place to place by sound, light, heat, and electric currents.

Clarification Statement:
- Evidence of energy being transferred can include vibrations felt a small distance from a source, a solar-powered toy that moves when placed in direct light, warming a metal object on one end and observing the other end getting warm, and a wire carrying electric energy from a battery to light a bulb.

State Assessment Boundary:
- Quantitative measurements of energy are not expected in state assessment.

4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.

Clarification Statement:
- Changes in energy can include a change in the object's motion, position, and the generation of heat and/or sound.

State Assessment Boundary:
- Analysis of forces or quantitative measurements of energy are not expected in state assessment.

4-PS3-4. Apply scientific principles of energy and motion to test and refine a device that converts kinetic energy to electrical energy or uses stored energy to cause motion or produce light or sound.*
Clarification Statement:
- Sources of stored energy can include water in a bucket or a weight suspended at a height, and a battery.

PS4. Waves and Their Applications in Technologies for Information Transfer

4-PS4-1. Develop a model of a simple mechanical wave (including sound) to communicate that waves (a) are regular patterns of motion along which energy travels and (b) can cause objects to move.
Clarification Statement:
- Examples of models could include diagrams, analogies, and physical models.
State Assessment Boundary:
- Interference effects, electromagnetic waves, or non-periodic waves are not expected in state assessment.
4-PS4-2. Develop a model to describe that light must reflect off an object and enter the eye for the object to be seen.
State Assessment Boundary:
- Specific colors reflected and seen, the cellular mechanisms of vision, angles of incidence and reflection, or how the retina works are not expected in state assessment.
4-PS4-3. Develop and compare multiple ways to transfer information through encoding, sending, receiving, and decoding a pattern.*
Clarification Statement:
- Examples of solutions could include drums sending coded information through sound waves, using a grid of 1s and 0s representing black and white to send information about a picture, and using Morse code to send text.

Grade 4: Technology/Engineering

ETS1. Engineering Design

4.3-5-ETS1-3. Plan and carry out tests of one or more design features of a given model or prototype in which variables are controlled and failure points are considered to identify which features need to be improved. Apply the results of tests to redesign a model or prototype.*
Clarification Statement:
- Examples of design features can include materials, size, shape, and weight.
4.3-5-ETS1-5(MA). Evaluate relevant design features that must be considered in building a model or prototype of a solution to a given design problem.*

[3-5-ETS1-1, 3-5-ETS1-2, and 3-5-ETS1-4(MA) are found in grade 3.]

Grade 5

Connections and Relationships in Systems

In grade 5, students model, provide evidence to support arguments, and obtain and display data about relationships and interactions among observable components of different systems. By studying systems, grade 5 students learn that objects and organisms do not exist in isolation and that animals, plants and their environments are connected to, interact with, and are influenced by each other. They study the relationships between Earth and other nearby objects in the solar system and the impact of those relationships on patterns of events as seen from Earth. They learn about the relationship among elements of Earth's systems through the cycling of water and human practices and processes with Earth's resources. They also learn about the connections and relationships among plants and animals, and the ecosystems within which they live, to show how matter and energy are cycled through these (building on the theme of grade 4). An ability to describe, analyze, and model connections and relationships of observable components of different systems is key to understanding the natural and designed world.

Grade 5: Earth and Space Sciences

ESS1. Earth's Place in the Universe

5-ESS1-1. Use observations, first-hand and from various media, to argue that the Sun is a star that appears larger and brighter than other stars because it is closer to Earth.
    State Assessment Boundary:
- Other factors that affect apparent brightness (such as stellar masses, age, or stage) are not expected in state assessment.

5-ESS1-2. Use a model to communicate Earth's relationship to the Sun, Moon, and other stars that explain (a) why people on Earth experience day and night, (b) patterns in daily changes in length and direction of shadows over a day, and (c) changes in the apparent position of the Sun, Moon, and stars at different times during a day, over a month, and over a year.
    Clarification Statement:
- Models should illustrate that the Earth, Sun, and Moon are spheres; include orbits of the Earth around the Sun and of the Moon around Earth; and demonstrate Earth's rotation about its axis.

    State Assessment Boundary:
- Causes of lunar phases or seasons, or use of Earth's tilt are not expected in state assessment.

ESS2. Earth's Systems

5-ESS2-1. Use a model to describe the cycling of water through a watershed through evaporation, precipitation, absorption, surface runoff, and condensation.
    State Assessment Boundary:
- Transpiration or explanations of mechanisms that drive the cycle are not expected in state assessment.

5-ESS2-2. Describe and graph the relative amounts of salt water in the ocean; fresh water in lakes, rivers, and groundwater; and fresh water frozen in glaciers and polar ice caps to provide evidence about the availability of fresh water in Earth's biosphere.
    State Assessment Boundary:
- Inclusion of the atmosphere is not expected in state assessment.

ESS3. Earth and Human Activity

5-ESS3-1. Obtain and combine information about ways communities reduce human impact on the Earth's resources and environment by changing an agricultural, industrial, or community practice or process.
Clarification Statement:
- Examples of changed practices or processes include treating sewage, reducing the amounts of materials used, capturing polluting emissions from factories or power plants, and preventing runoff from agricultural activities.
State Assessment Boundary:
- Climate change or social science aspects of practices such as regulation or policy are not expected in state assessment.

5-ESS3-2(MA). Test a simple system designed to filter particulates out of water and propose one change to the design to improve it.*

Grade 5: Life Science

LS1. From Molecules to Organisms: Structures and Processes

5-LS1-1. Ask testable questions about the process by which plants use air, water, and energy from sunlight to produce sugars and plant materials needed for growth and reproduction.
State Assessment Boundary:
- The chemical formula or molecular details about the process of photosynthesis are not expected in state assessment.

LS2. Ecosystems: Interactions, Energy, and Dynamics

5-LS2-1. Develop a model to describe the movement of matter among producers, consumers, decomposers, and the air, water, and soil in the environment to (a) show that plants produce sugars and plant materials, (b) show that animals can eat plants and/or other animals for food, and (c) show that some organisms, including fungi and bacteria, break down dead organisms and recycle some materials back to the air and soil.
Clarification Statement:
- Emphasis is on matter moving throughout the ecosystem.
State Assessment Boundary:
- Molecular explanations, or distinctions among primary, secondary, and tertiary consumers, are not expected in state assessment.

5-LS2-2(MA). Compare at least two designs for a composter to determine which is most likely to encourage decomposition of materials.*
Clarification Statement:
- Measures or evidence of decomposition should be on qualitative descriptions or comparisons.

Grade 5: Physical Science

PS1. Matter and Its Interactions

5-PS1-1. Use a particle model of matter to explain common phenomena involving gases, and phase changes between gas and liquid and between liquid and solid.
Clarification Statement:

- Examples of common phenomena the model should be able to describe include adding air to expand a balloon, compressing air in a syringe, and evaporating water from a salt water solution.

State Assessment Boundary:
- Atomic-scale mechanisms of evaporation and condensation or defining unseen particles are not expected in state assessment.

5-PS1-2. Measure and graph the weights (masses) of substances before and after a reaction or phase change to provide evidence that regardless of the type of change that occurs when heating, cooling, or combining substances, the total weight (mass) of matter is conserved.

Clarification Statement:
- Assume that reactions with any gas production are conducted in a closed system.

State Assessment Boundary:
- Distinguishing mass and weight is not expected in state assessment.

5-PS1-3. Make observations and measurements of substances to describe characteristic properties of each, including color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility.

Clarification Statements:
- Emphasis is on describing how each substance has a unique set of properties.
- Examples of substances could include baking soda and other powders, metals, minerals, and liquids.

State Assessment Boundary:
- Density, distinguishing mass and weight, or specific tests or procedures are not expected in state assessment.

5-PS1-4. Conduct an experiment to determine whether the mixing of two or more substances results in new substances with new properties (a chemical reaction) or not (a mixture).

PS2. Motion and Stability: Forces and Interactions

5-PS2-1. Support an argument with evidence that the gravitational force exerted by Earth on objects is directed toward Earth's center.

State Assessment Boundary:
- Mathematical representations of gravitational force are not expected in state assessment.

PS3. Energy

5-PS3-1. Use a model to describe that the food animals digest (a) contains energy that was once energy from the Sun, and (b) provides energy and nutrients for life processes, including body repair, growth, motion, body warmth, and reproduction.

Clarification Statement:
- Examples of models could include diagrams and flow charts.

State Assessment Boundary:
- Details of cellular respiration, ATP, or molecular details of the process of photosynthesis or respiration are not expected in state assessment.

ETS3. Technological Systems

5.3-5-ETS3-1(MA). Use informational text to provide examples of improvements to existing technologies (innovations) and the development of new technologies (inventions). Recognize that technology is any modification of the natural or designed world done to fulfill human needs or wants.

5.3-5-ETS3-2(MA). Use sketches or drawings to show how each part of a product or device relates to other parts in the product or device.*

Grades 6–8: Overview of Science and Engineering Practices

Active engagement of middle school students with the science and engineering practices is critical: students generally make up their minds about whether they identify with science and engineering by the time they leave grade 8, and whether they will pursue these fields in high school and beyond. Students must have opportunities to develop the skills necessary for a meaningful progression of development in order to engage in scientific and technical reasoning so critical to success in civic life, postsecondary education, and careers. Inclusion of science and engineering practices in standards only speaks to the types of performances students should be able to demonstrate at the end of instruction at a particular grade; the standards do not limit what educators and students should or can be engaged in through a well-rounded curriculum.

Standards for grades 6 through 8 integrate all eight science and engineering practices. Students' understanding of and ability with each practice gets more detailed and sophisticated through middle school. For example, by the end of middle school, students can identify limitations of a particular model, including limitations of its accuracy, what features are included (or not), and limitations of what phenomena or outcomes it can predict. Students can develop models of varying levels of detail and accuracy and can identify when a situation calls for a conceptual model with little detail or a specific model with attention to accuracy, such as for making predictions of particular events.

Some examples of specific skills students should develop in these grades:

1. Define criteria and constraints of a design problem with precision.

2. Develop a model to describe cycling of matter in an ecosystem; develop a model that describes and predicts changes in particle motion and spatial arrangement during phase changes; develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.

3. Conduct an investigation to show relationships among energy transfer, type of matter, and kinetic energy of particles; conduct an experiment to show that many materials are mixtures.

4. Examine and interpret data to describe the role human activities have played in the rise of global temperatures over time; construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships; distinguish between causal and correlational relationships in data; consider limitations of data analysis.

5. Describe, including through probability statements and proportional reasoning, the process of natural selection; use data and graphs to describe relationships among kinetic energy, mass, and speed of an object.

6. Construct an explanation using evidence for how Earth's surface has changed over time; apply scientific reasoning to show why the data or evidence is adequate for the explanation.

7. Construct an argument based on evidence for how environmental and genetic factors influence organism growth; respectfully provide and receive critiques about one's arguments, procedures, and models by citing relevant evidence with pertinent detail.

8. Synthesize and communicate information about artificial selection; obtain and communicate information on how past geologic events are analyzed to make future predictions.

While presented as distinct skill sets, the eight practices intentionally overlap and interconnect. Skills such as those outlined above should be reflected in curricula and instruction that engage students in an integrated use of the practices. See the Science and Engineering Practices Progression Matrix (Appendix I) for more information, including particular skills for students in grades 6–8.

Grade 6

Structure and Function

The integration of Earth and space, life, and physical sciences with technology/engineering gives grade 6 students relevant and engaging opportunities with natural phenomena and design problems that highlight the relationship of structure and function in the world around them. Students relate structure and function through analyzing the macro- and microscopic world, such as Earth features and processes, the role of cells and anatomy in supporting living organisms, and properties of materials and waves. Students use models and provide evidence to make claims and explanations about structure-function relationships in different STE domains.

Grade 6: Earth and Space Sciences

ESS1. Earth's Place in the Universe

6.MS-ESS1-1a. Develop and use a model of the Earth-Sun-Moon system to explain the causes of lunar phases and eclipses of the Sun and Moon.
  Clarification Statement:
  • Examples of models can be physical, graphical, or conceptual and should emphasize relative positions and distances.
6.MS-ESS1-4. Analyze and interpret rock layers and index fossils to determine the relative ages of rock formations that result from processes occurring over long periods of time.
  Clarification Statements:
  • Analysis includes laws of superposition and crosscutting relationships limited to minor displacement faults that offset layers.
  • Processes that occur over long periods of time include changes in rock types through weathering, erosion, heat, and pressure.
  State Assessment Boundary:
  • Strata sequences that have been reordered or overturned, names of specific periods or epochs and events within them, or the identification and naming of minerals or rock types are not expected in state assessment.
6.MS-ESS1-5(MA). Use graphical displays to illustrate that Earth and its solar system are one of many in the Milky Way galaxy, which is one of billions of galaxies in the universe.
  Clarification Statement:
  • Graphical displays can include maps, charts, graphs, and data tables.

[MS-ESS1-1b and MS-ESS1-2 are found in grade 8. MS-ESS1-3 from NGSS is not included.]

ESS2. Earth's Systems

6.MS-ESS2-3. Analyze and interpret maps showing the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence that Earth's plates have moved great distances, collided, and spread apart.
  Clarification Statement:
  • Maps may show 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), similar to Wegener's visuals.
  State Assessment Boundary:
  • Mechanisms for plate motion or paleomagnetic anomalies in oceanic and continental crust are not expected in state assessment.

Grade 6: Life Science

LS1. From Molecules to Organisms: Structures and Processes

6.MS-LS1-1. Provide evidence that all organisms (unicellular and multicellular) are made of cells.
Clarification Statement:
- Evidence can be drawn from multiple types of organisms, such as plants, animals, and bacteria.

6.MS-LS1-2. Develop and use a model to describe how parts of cells contribute to the cellular functions of obtaining food, water, and other nutrients from its environment, disposing of wastes, and providing energy for cellular processes.
Clarification Statement:
- Parts of plant and animal cells include (a) the nucleus, which contains a cell's genetic material and regulates its activities; (b) chloroplasts, which produce necessary food (sugar) and oxygen through photosynthesis (in plants); (c) mitochondria, which release energy from food through cellular respiration; (d) vacuoles, which store materials, including water, nutrients, and waste; (e) the cell membrane, which is a selective barrier that enables nutrients to enter the cell and wastes to be expelled; and (f) the cell wall, which provides structural support (in plants).
State Assessment Boundary:
- Specific biochemical steps or chemical processes, the role of ATP, active transport processes involving the cell membrane, or identifying or comparing different types of cells are not expected in state assessment.

6.MS-LS1-3. Construct an argument supported by evidence that the body systems interact to carry out essential functions of life.
Clarification Statements:
- Emphasis is on the functions and interactions of the body systems, not specific body parts or organs.
- An argument should convey that different types of cells can join together to form specialized tissues, which in turn may form organs that work together as body systems.
- Body systems to be included are the circulatory, digestive, respiratory, excretory, muscular/skeletal, and nervous systems.
- Essential functions of life include obtaining food and other nutrients (water, oxygen, minerals), releasing energy from food, removing wastes, responding to stimuli, maintaining internal conditions, and growing/developing.
- An example of interacting systems could include the respiratory system taking in oxygen from the environment which the circulatory system delivers to cells for cellular respiration, or the digestive system taking in nutrients which the circulatory system transports to cells around the body.
State Assessment Boundaries:
- The mechanism of one body system independent of others or the biochemical processes involved in body systems are not expected in state assessment.
- Describing the function or comparing different types of cells, tissues, or organs are not expected in state assessment.

LS4. Biological Evolution: Unity and Diversity

6.MS-LS4-1. Analyze and interpret evidence from the fossil record to describe organisms and their environment, extinctions, and changes to life forms throughout the history of Earth.
    Clarification Statement:
    - Examples of evidence include sets of fossils that indicate a specific type of environment, anatomical structures that indicate the function of an organism in the environment, and fossilized tracks that indicate behavior of organisms.
    State Assessment Boundary:
    - Names of individual species, geological eras in the fossil record, or mechanisms for extinction or speciation are not expected in state assessment.
6.MS-LS4-2. Construct an argument using anatomical structures to support evolutionary relationships among and between fossil organisms and modern organisms.
    Clarification Statement:
    - Evolutionary relationships include (a) some organisms have similar traits with similar functions because they were inherited from a common ancestor, (b) some organisms have similar traits that serve similar functions because they live in similar environments, and (c) some organisms have traits inherited from common ancestors that no longer serve their original function because their environments are different than their ancestors' environments.

[MS-LS4-4 and MS-LS4-5 are found in grade 8. MS-LS4-3 and MS-LS4-6 from NGSS are not included.]

Grade 6: Physical Science

PS1. Matter and Its Interactions

6.MS-PS1-6. Plan and conduct an experiment involving exothermic and endothermic chemical reactions to measure and describe the release or absorption of thermal energy.
    Clarification Statements:
    - Emphasis is on describing transfer of energy to and from the environment.
    - Examples of chemical reactions could include dissolving ammonium chloride or calcium chloride.
6.MS-PS1-7(MA). Use a particulate model of matter to explain that density is the amount of matter (mass) in a given volume. Apply proportional reasoning to describe, calculate, and compare relative densities of different materials.
6.MS-PS1-8(MA). Conduct an experiment to show that many materials are mixtures of pure substances that can be separated by physical means into their component pure substances.
    Clarification Statement:
    - Examples of common mixtures include salt water, oil and vinegar, milk, and air.

[MS-PS1-1, MS-PS1-2, MS-PS1-4, and MS-PS1-5 are found in grade 8. MS-PS1-3 from NGSS is not included.]

PS2. Motion and Stability: Forces and Interactions

6.MS-PS2-4. Use evidence to support the claim that gravitational forces between objects are attractive and are only noticeable when one or both of the objects have a very large mass.
    Clarification Statement:
    - Examples of objects with very large masses include the Sun, Earth, and other planets.
    State Assessment Boundary:
    - Newton's law of gravitation or Kepler's laws are not expected in state assessment.

[MS-PS2-3 and MS-PS2-5 are found in grade 7. MS-PS2-1 and MS-PS2-2 are found in grade 8.]

6.MS-PS4-1. Use diagrams of a simple wave to explain that (a) a wave has a repeating pattern with a specific amplitude, frequency, and wavelength, and (b) the amplitude of a wave is related to the energy of the wave.
  State Assessment Boundaries:
  - Electromagnetic waves are not expected in state assessment.
  - State assessment will be limited to standard repeating waves.

6.MS-PS4-2. Use diagrams and other models to show that both light rays and mechanical waves are reflected, absorbed, or transmitted through various materials.
  Clarification Statements:
  - Materials may include solids, liquids, and gases.
  - Mechanical waves (including sound) need a material (medium) through which they are transmitted.
  - Examples of models could include drawings, simulations, and written descriptions.
  State Assessment Boundary:
  - State assessment will be limited to qualitative applications.

6.MS-PS4-3. Present qualitative scientific and technical information to support the claim that digitized signals (sent as wave pulses representing 0s and 1s) can be used to encode and transmit information.
  State Assessment Boundary:
  - Binary counting or the specific mechanism of any given device are not expected in state assessment.

Grade 6: Technology/Engineering

ETS1. Engineering Design

6.MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution. Include potential impacts on people and the natural environment that may limit possible solutions.*

6.MS-ETS1-5(MA). Create visual representations of solutions to a design problem. Accurately interpret and apply scale and proportion to visual representations.*
  Clarification Statements:
  - Examples of visual representations can include sketches, scaled drawings, and orthographic projections.
  - Examples of scale can include ¼″ = 1′0″ and 1 cm = 1 m.

6.MS-ETS1-6(MA). Communicate a design solution to an intended user, including design features and limitations of the solution.
  Clarification Statement:
  - Examples of intended users can include students, parents, teachers, manufacturing personnel, engineers, and customers.

[MS-ETS1-2, MS-ETS1-4, and MS-ETS1-7(MA) are found in grade 7. MS-ETS1-3 from NGSS is not included.]

ETS2. Materials, Tools, and Manufacturing

6.MS-ETS2-1(MA). Analyze and compare properties of metals, plastics, wood, and ceramics, including flexibility, ductility, hardness, thermal conductivity, electrical conductivity, and melting point.

6.MS-ETS2-2(MA). Given a design task, select appropriate materials based on specific properties needed in the construction of a solution.*

Clarification Statement:
- Examples of materials can include metals, plastics, wood, and ceramics.

6.MS-ETS2-3(MA). Choose and safely use appropriate measuring tools, hand tools, fasteners, and common hand-held power tools used to construct a prototype.*

Clarification Statements:
- Examples of measuring tools include a tape measure, a meter stick, and a ruler.
- Examples of hand tools include a hammer, a screwdriver, a wrench, and pliers.
- Examples of fasteners include nails, screws, nuts and bolts, staples, glue, and tape.
- Examples of common power tools include jigsaw, drill, and sander.

[MS-ETS2-4(MA), and MS-ETS2-5(MA) are found in grade 8.]

Grade 7

Systems and Cycles

Students in grade 7 focus on systems and cycles using their understanding of structures and functions, connections and relationships in systems, and flow of matter and energy developed in earlier grades. A focus on systems requires students to apply concepts and skills across disciplines, since most natural and designed systems and cycles are complex and interactive. They gain experience with plate tectonics, interactions of humans and Earth processes, organism systems to support and propagate life, ecosystem dynamics, motion and energy systems, and key technological systems used by society. Through grade 7, students begin a process of moving from a more concrete to an abstract perspective, since many of the systems and cycles studied are not directly observable or experienced. This also creates a foundation for exploring cause and effect relationships in more depth in grade 8.

Grade 7: Earth and Space Sciences

ESS2. Earth's Systems

7.MS-ESS2-2. Construct an explanation based on evidence for how Earth's surface has changed over scales that range from local to global in size.
  Clarification Statements:
  - Examples of processes occurring over large, global spatial scales include plate motion, formation of mountains and ocean basins, and ice ages.
  - Examples of changes occurring over small, local spatial scales include earthquakes and seasonal weathering and erosion.

7.MS-ESS2-4. Develop a model to explain how the energy of the Sun and Earth's gravity drive the cycling of water, including changes of state, as it moves through multiple pathways in Earth's hydrosphere.
  Clarification Statement:
  - Examples of models can be conceptual or physical.
  State Assessment Boundary:
  - A quantitative understanding of the latent heats of vaporization and fusion is not expected in state assessment.

[MS-ESS2-3 is found in grade 6. MS-ESS2-1, MS-ESS2-5, and MS-ESS2-6 are found in grade 8.]

ESS3. Earth and Human Activity

7.MS-ESS3-2. Obtain and communicate information on how data from past geologic events are analyzed for patterns and used to forecast the location and likelihood of future catastrophic events.
  Clarification Statements:
  - Geologic events include earthquakes, volcanic eruptions, floods, and landslides.
  - Examples of data typically analyzed can include the locations, magnitudes, and frequencies of the natural hazards.
  State Assessment Boundary:
  - Active analysis of data or forecasting is not expected in state assessment.

7.MS-ESS3-4. Construct an argument supported by evidence that human activities and technologies can mitigate the impact of increases in human population and per capita consumption of natural resources on the environment.

Clarification Statements:
- Arguments should be based on examining historical data such as population graphs, natural resource distribution maps, and water quality studies over time.
- Examples of negative impacts can include changes to the amount and quality of natural resources such as water, mineral, and energy supplies.

[MS-ESS3-1 and MS-ESS3-5 are found in grade 8. MS-ESS3-3 from NGSS has been merged with MS-ESS3-4.]

Grade 7: Life Science

LS1. From Molecules to Organisms: Structures and Processes

7.MS-LS1-4. Construct an explanation based on evidence for how characteristic animal behaviors and specialized plant structures increase the probability of successful reproduction of animals and plants.

Clarification Statements:
- Examples of animal behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalizations and colorful plumage to attract mates for breeding.
- Examples of animal behaviors that affect the probability of plant reproduction could include (a) transferring pollen or seeds and (b) creating conditions for seed germination and growth.
- Examples of plant structures that affect the probability of plant reproduction could include bright flowers attracting butterflies that transfer pollen, flower nectar, and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.

State Assessment Boundary:
- Natural selection is not expected in state assessment.

[MS-LS1-1, MS-LS1-2, and MS-LS1-3 are found in grade 6. MS-LS1-5 and MS-LS1-7 are found in grade 8. MS-LS1-6 and MS-LS1-8 from NGSS are not included.]

LS2. Ecosystems: Interactions, Energy, and Dynamics

7.MS-LS2-1. Analyze and interpret data to provide evidence for the effects of periods of abundant and scarce resources on the growth of organisms and the size of populations in an ecosystem.

7.MS-LS2-2. Describe how relationships among and between organisms in an ecosystem can be competitive, predatory, parasitic, and mutually beneficial and that these interactions are found across multiple ecosystems.

Clarification Statement:
- Emphasis is on describing consistent patterns of interactions in different ecosystems in terms of relationships among and between organisms.

7.MS-LS2-3. Develop a model to describe that matter and energy are transferred among living and nonliving parts of an ecosystem and that both matter and energy are conserved through these processes.

Clarification Statements:
- Cycling of matter should include the role of photosynthesis, cellular respiration, and decomposition, as well as transfer among producers, consumers (primary, secondary, and tertiary), and decomposers.
- Models may include food webs and food chains.

State Assessment Boundary:
- Cycling of specific atoms (such as carbon or oxygen), or the biochemical steps of photosynthesis, cellular respiration, and decomposition are not expected in state assessment.

7.MS-LS2-4. Analyze data to provide evidence that disruptions (natural or human-made) to any physical or biological component of an ecosystem can lead to shifts in all its populations.
Clarification Statement:
- Focus should be on ecosystem characteristics varying over time, including disruptions such as hurricanes, floods, wildfires, oil spills, and construction.

7.MS-LS2-5. Evaluate competing design solutions for protecting an ecosystem. Discuss benefits and limitations of each design.*
Clarification Statements:
- Examples of design solutions could include water, land, and species protection and the prevention of soil erosion.
- Examples of design solution constraints could include scientific, economic, and social considerations.

7.MS-LS2-6(MA). Explain how changes to the biodiversity of an ecosystem—the variety of species found in the ecosystem—may limit the availability of resources humans use.
Clarification Statement:
Examples of resources can include food, energy, medicine, and clean water.

Grade 7: Physical Science

PS2. Motion and Stability: Forces and Interactions

7.MS-PS2-3. Analyze data to describe the effect of distance and magnitude of electric charge on the strength of electric forces.
Clarification Statement:
- Includes both attractive and repulsive forces.
State Assessment Boundaries:
- State assessment will be limited to proportional reasoning.
- Calculations using Coulomb's law or interactions of sub-atomic particles are not expected in state assessment.

7.MS-PS2-5. Use scientific evidence to argue that fields exist between objects with mass, between magnetic objects, and between electrically charged objects that exert force on each other even though the objects are not in contact.
Clarification Statement:
- Emphasis is on evidence that demonstrates the existence of fields, limited to gravitational, electric, and magnetic fields.
State Assessment Boundary:
- Calculations of force are not expected in state assessment.

[MS-PS2-4 is found in grade 6. MS-PS2-1 and MS-PS2-2 are found in grade 8.]

PS3. Energy

7.MS-PS3-1. Construct and interpret data and graphs to describe the relationships among kinetic energy, mass, and speed of an object.
  Clarification Statements:
  - Examples could include riding a bicycle at different speeds and rolling different-sized rocks downhill.
  - Consider relationships between kinetic energy vs. mass and kinetic energy vs. speed separate from each other; emphasis is on the difference between the linear and exponential relationships.
  State Assessment Boundary:
  - Calculation or manipulation of the formula for kinetic energy is not expected in state assessment.

7.MS-PS3-2. Develop a model to describe the relationship between the relative positions of objects interacting at a distance and their relative potential energy in the system.
  Clarification Statements:
  - Examples of objects within systems interacting at varying distances could include Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a stream of water.
  - Examples of models could include representations, diagrams, pictures, and written descriptions of systems.
  State Assessment Boundaries:
  - State assessment will be limited to electric, magnetic, and gravitational interactions and to interactions of two objects at a time.
  - Calculations of potential energy are not expected in state assessment.

7.MS-PS3-3. Apply scientific principles of energy and heat transfer to design, construct, and test a device to minimize or maximize thermal energy transfer.*
  Clarification Statement:
  - Examples of devices could include an insulated box, a solar cooker, and a vacuum flask.
  State Assessment Boundary:
  - Accounting for specific heat or calculations of the total amount of thermal energy transferred is not expected in state assessment.

7.MS-PS3-4. Conduct an investigation to determine the relationships among the energy transferred, how well the type of matter retains or radiates heat, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
  State Assessment Boundary:
  - Calculations of specific heat or the total amount of thermal energy transferred are not expected in state assessment.

7.MS-PS3-5. Present evidence to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
  Clarification Statement:
  - Examples of empirical evidence could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of an object.
  State Assessment Boundary:
  - Calculations of energy are not expected in state assessment.

7.MS-PS3-6(MA). Use a model to explain how thermal energy is transferred out of hotter regions or objects and into colder ones by convection, conduction, and radiation.

7.MS-PS3-7(MA). Use informational text to describe the relationship between kinetic and potential energy and illustrate conversions from one form to another.
 Clarification Statement:
- Types of kinetic energy include motion, sound, thermal, and light; types of potential energy include gravitational, elastic, and chemical.

Grade 7: Technology/Engineering

ETS1. Engineering Design

7.MS-ETS1-2. Evaluate competing solutions to a given design problem using a decision matrix to determine how well each meets the criteria and constraints of the problem. Use a model of each solution to evaluate how variations in one or more design features, including size, shape, weight, or cost, may affect the function or effectiveness of the solution.*

7.MS-ETS1-4. Generate and analyze data from iterative testing and modification of a proposed object, tool, or process to optimize the object, tool, or process for its intended purpose.*

7.MS-ETS1-7(MA). Construct a prototype of a solution to a given design problem.*

[MS-ETS1-1, MS-ETS1-5(MA), and MS-ETS1-6(MA) are found in grade 6. MS-ETS1-3 from NGSS is not included.]

ETS3. Technological Systems

7.MS-ETS3-1(MA). Explain the function of a communication system and the role of its components, including a source, encoder, transmitter, receiver, decoder, and storage.

7.MS-ETS3-2(MA). Compare the benefits and drawbacks of different communication systems.
 Clarification Statements:
- Examples of communications systems can include radio, television, print, and Internet.
- Examples of benefits and drawbacks can include speed of communication, distance or range, number of people reached, audio only vs. audio and visual, and one-way vs. two-way communication.

7.MS-ETS3-3(MA). Research and communicate information about how transportation systems are designed to move people and goods using a variety of vehicles and devices. Identify and describe subsystems of a transportation vehicle, including structural, propulsion, guidance, suspension, and control subsystems.
 Clarification Statements:
- Examples of design elements include vehicle shape to maximize cargo or passenger capacity, terminals, travel lanes, and communications/controls.
- Examples of vehicles can include a car, sailboat, and small airplane.

7.MS-ETS3-4(MA). Show how the components of a structural system work together to serve a structural function. Provide examples of physical structures and relate their design to their intended use.
 Clarification Statements:
- Examples of components of a structural system could include foundation, decking, wall, and roofing.
- Explanations of function should include identification of live vs. dead loads and forces of tension, torsion, compression, and shear.
- Examples of uses include carrying loads and forces across a span (such as a bridge), providing livable space (such as a house or office building), and providing specific environmental conditions (such as a greenhouse or cold storage).
 State Assessment Boundary:
- Calculations of magnitude or direction of loads or forces are not expected in state assessment.

7.MS-ETS3-5(MA). Use the concept of systems engineering to model inputs, processes, outputs, and feedback among components of a transportation, structural, or communication system.

Grade 8

Cause and Effect

Grade 8 students use more robust abstract thinking skills to explain causes of complex phenomena and systems. Many causes are not immediately or physically visible to students. An understanding of cause and effect of key natural phenomena and designed processes allows students to explain patterns and make predictions about future events. In grade 8 these include, for example, causes of seasons and tides; causes of plate tectonics and weather or climate; the role of genetics in reproduction, heredity, and artificial selection; and how atoms and molecules interact to explain the substances that make up the world and how materials change. Being able to analyze phenomena for evidence of causes and processes that often cannot be seen, and being able to conceptualize and describe those, is a significant outcome for grade 8 students.

Grade 8: Earth and Space Sciences

ESS1. Earth's Place in the Universe

8.MS-ESS1-1b. Develop and use a model of the Earth-Sun system to explain the cyclical pattern of seasons, which includes Earth's tilt and differential intensity of sunlight on different areas of Earth across the year.
  Clarification Statement:
   • Examples of models can be physical or graphical.
8.MS-ESS1-2. Explain the role of gravity in ocean tides, the orbital motions of planets, their moons, and asteroids in the solar system.
  State Assessment Boundary:
   • Kepler's laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth are not expected in state assessment.

[MS-ESS1-1a, MS-ESS1-4, and MS-ESS1-5 are found in grade 6. MS-ESS1-3 from NGSS is not included.]

ESS2. Earth's Systems

8.MS-ESS2-1. Use a model to illustrate that energy from Earth's interior drives convection that cycles Earth's crust, leading to melting, crystallization, weathering, and deformation of large rock formations, including generation of ocean sea floor at ridges, submergence of ocean sea floor at trenches, mountain building, and active volcanic chains.
  Clarification Statement:
   • The emphasis is on large-scale cycling resulting from plate tectonics.
8.MS-ESS2-5. Interpret basic weather data to identify patterns in air mass interactions and the relationship of those patterns to local weather.
  Clarification Statements:
   • Data includes temperature, pressure, humidity, precipitation, and wind.
   • Examples of patterns can include air masses flow from regions of high pressure to low pressure, and how sudden changes in weather can result when different air masses collide.
   • Data can be provided to students (such as in weather maps, data tables, diagrams, or visualizations) or obtained through field observations or laboratory experiments.
  State Assessment Boundary:
   • Specific names of cloud types or weather symbols used on weather maps are not expected in state assessment.

8.MS-ESS2-6. Describe how interactions involving the ocean affect weather and climate on a regional scale, including the influence of the ocean temperature as mediated by energy input from the Sun and energy loss due to evaporation or redistribution via ocean currents.
Clarification Statement:
- A regional scale includes a state or multi-state perspective.

State Assessment Boundary:
- Koppen Climate Classification names are not expected in state assessment.

[MS-ESS2-3 is found in grade 6. MS-ESS2-2 and MS-ESS2-4 are found in grade 7.]

ESS3. Earth and Human Activity

8.MS-ESS3-1. Analyze and interpret data to explain that the Earth's mineral and fossil fuel resources are unevenly distributed as a result of geologic processes.
Clarification Statement:
- Examples of uneven distributions of resources can include where petroleum is generally found (locations of the burial of organic marine sediments and subsequent geologic traps), and where metal ores are generally found (locations of past volcanic and hydrothermal activity).

8.MS-ESS3-5. Examine and interpret data to describe the role that human activities have played in causing the rise in global temperatures over the past century.
Clarification Statements:
- Examples of human activities include fossil fuel combustion, deforestation, and agricultural activity.
- Examples of evidence can include tables, graphs, and maps of global and regional temperatures; atmospheric levels of gases such as carbon dioxide and methane; and the rates of human activities.

[MS-ESS3-2 and MS-ESS3-4 are found in grade 7. MS-ESS3-3 from NGSS has been merged with MS-ESS3-4.]

Grade 8: Life Science

LS1. From Molecules to Organisms: Structures and Processes

8.MS-LS1-5. Construct an argument based on evidence for how environmental and genetic factors influence the growth of organisms.
Clarification Statements:
- Examples of environmental conditions could include availability of food, light, space, and water.
- Examples of genetic factors could include the genes responsible for size differences in different breeds of dogs, such as Great Danes and Chihuahuas.
- Examples of environmental factors could include drought decreasing plant growth, fertilizer increasing plant growth, and fish growing larger in large ponds than they do in small ponds.
- Examples of both genetic and environmental factors could include different varieties of plants growing at different rates in different conditions.

State Assessment Boundary:
- Methods of reproduction, genetic mechanisms, gene regulation, biochemical processes, or natural selection are not expected in state assessment.

8.MS-LS1-7. Use informational text to describe that food molecules, including carbohydrates, proteins, and fats, are broken down and rearranged through chemical reactions forming new molecules that support cell growth and/or release of energy.
State Assessment Boundary:
- Specific details of the chemical reaction for cellular respiration, biochemical steps of breaking down food, or the resulting molecules (e.g., carbohydrates are broken down into monosaccharides) are not expected in state assessment.

[MS-LS1-1, MS-LS1-2, and MS-LS1-3 are found in grade 6. MS-LS1-4 is found in grade 7. MS-LS1-6 and MS-LS1-8 from NGSS are not included.]

LS3. Heredity: Inheritance and Variation of Traits

8.MS-LS3-1. Develop and use a model to describe that structural changes to genes (mutations) may or may not result in changes to proteins, and if there are changes to proteins there may be harmful, beneficial, or neutral changes to traits.
Clarification Statements:
- An example of a beneficial change to the organism may be a strain of bacteria becoming resistant to an antibiotic.
- A harmful change could be the development of cancer; a neutral change may change the hair color of an organism with no direct consequence.
State Assessment Boundary:
- Specific changes at the molecular level (e.g., amino acid sequence change), mechanisms for protein synthesis, or specific types of mutations are not expected in state assessment.

8.MS-LS3-2. Construct an argument based on evidence for how asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. Compare and contrast advantages and disadvantages of asexual and sexual reproduction.
Clarification Statements:
- Examples of an advantage of sexual reproduction can include genetic variation when the environment changes or a disease is introduced, while examples of an advantage of asexual reproduction can include not using energy to find a mate and fast reproduction rates.
- Examples of a disadvantage of sexual reproduction can include using resources to find a mate, while a disadvantage in asexual reproduction can be the lack of genetic variation when the environment changes or a disease is introduced.

8.MS-LS3-3(MA). Communicate through writing and in diagrams that chromosomes contain many distinct genes and that each gene holds the instructions for the production of specific proteins, which in turn affects the traits of an individual.
State Assessment Boundary:
- Specific changes at the molecular level or mechanisms for protein synthesis are not expected in state assessment.

8.MS-LS3-4(MA). Develop and use a model to show that sexually reproducing organisms have two of each chromosome in their cell nuclei, and hence two variants (alleles) of each gene that can be the same or different from each other, with one random assortment of each chromosome passed down to offspring from both parents.
Clarification Statement:
- Examples of models can include Punnett squares, diagrams (e.g., simple pedigrees), and simulations.
State Assessment Boundary:
- State assessment will limit inheritance patterns to dominant-recessive alleles only.

LS4. Biological Evolution: Unity and Diversity

8.MS-LS4-4. Use a model to describe the process of natural selection, in which genetic variations of some traits in a population increase some individuals' likelihood of surviving and reproducing in a changing environment. Provide evidence that natural selection occurs over many generations.
    Clarification Statements:
- The model should include simple probability statements and proportional reasoning.
- Examples of evidence can include Darwin's finches, necks of giraffes, and peppered moths.

    State Assessment Boundary:
- Specific conditions that lead to natural selection are not expected in state assessment.

8.MS-LS4-5. Synthesize and communicate information about artificial selection, or the ways in which humans have changed the inheritance of desired traits in organisms.
    Clarification Statement:
- Emphasis is on the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, and gene therapy).

[MS-LS4-1 and MS-LS4-2 are found in grade 6. MS-LS4-3 and MS-LS4-6 from NGSS are not included.]

Grade 8: Physical Science

PS1. Matter and Its Interactions

8.MS-PS1-1. Develop a model to describe that (a) atoms combine in a multitude of ways to produce pure substances which make up all of the living and nonliving things that we encounter, (b) atoms form molecules and compounds that range in size from two to thousands of atoms, and (c) mixtures are composed of different proportions of pure substances.
    Clarification Statement:
- Examples of molecular-level models could include drawings, three-dimensional ball and stick structures, and computer representations showing different molecules with different types of atoms.

    State Assessment Boundary:
- Valence electrons and bonding energy, the ionic nature of subunits of complex structures, complete depictions of all individual atoms in a complex molecule or extended structure, or calculations of proportions in mixtures are not expected in state assessment.

8.MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
    Clarification Statements:
- Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with HCl.
- Properties of substances include density, melting point, boiling point, solubility, flammability, and odor.

8.MS-PS1-4. Develop a model that describes and predicts changes in particle motion, relative spatial arrangement, temperature, and state of a pure substance when thermal energy is added or removed.
    Clarification Statements:
- Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs.
- Examples of models could include drawings and diagrams.
- Examples of pure substances could include water, carbon dioxide, and helium.

8.MS-PS1-5. Use a model to explain that atoms are rearranged during a chemical reaction to form new substances with new properties. Explain that the atoms present in the reactants are all present in the products and thus the total number of atoms is conserved.
Clarification Statement:
- Examples of models can include physical models or drawings, including digital forms, that represent atoms.
State Assessment Boundary:
- Use of atomic masses, molecular weights, balancing symbolic equations, or intermolecular forces is not expected in state assessment.

[MS-PS1-6, MS-PS1-7(MA), and MS-PS1-8(MA) are found in grade 6. MS-PS1-3 from NGSS is not included.]

PS2. Motion and Stability: Forces and Interactions

8.MS-PS2-1. Develop a model that demonstrates Newton's third law involving the motion of two colliding objects.
State Assessment Boundary:
- State assessment will be limited to vertical or horizontal interactions in one dimension.
8.MS-PS2-2. Provide evidence that the change in an object's speed depends on the sum of the forces on the object (the net force) and the mass of the object.
Clarification Statement:
- Emphasis is on balanced (Newton's first law) and unbalanced forces in a system, qualitative comparisons of forces, mass, and changes in speed (Newton's second law) in one dimension.
State Assessment Boundaries:
- State assessment will be limited to forces and changes in motion in one dimension in an inertial reference frame and to change in one variable at a time.
- The use of trigonometry is not expected in state assessment.

[MS-PS2-4 is found in grade 6. MS-PS2-3 and MS-PS2-5 are found in grade 7.]

Grade 8: Technology/Engineering

ETS2. Materials, Tools, and Manufacturing

8.MS-ETS2-4(MA). Use informational text to illustrate that materials maintain their composition under various kinds of physical processing; however, some material properties may change if a process changes the particulate structure of a material.
Clarification Statements:
- Examples of physical processing can include cutting, forming, extruding, and sanding.
- Examples of changes in material properties can include a non-magnetic iron material becoming magnetic after hammering and a plastic material becoming rigid (less elastic) after heat treatment.
8.MS-ETS2-5(MA). Present information that illustrates how a product can be created using basic processes in manufacturing systems, including forming, separating, conditioning, assembling, finishing, quality control, and safety. Compare the advantages and disadvantages of human vs. computer control of these processes.

[MS-ETS2-1(MA), MS-ETS2-2(MA), and MS-ETS2-3(MA) are found in grade 6.]

High School: Overview of Science and Engineering Practices

The practices in grades 9–12 build on pre-K–8 experiences and progress to more technical and sophisticated applications to the natural and designed world we live in. The integration of science and engineering practices in high school science courses gives students dynamic and relevant opportunities to refine and communicate science understandings to be well prepared for civic life, postsecondary education, and career success. Essential competencies for students by the end of grade 12 include reading and comprehending relevant issues in science to be informed decision-makers. Accurately using mathematics and computation as it applies to daily life and engaging in the practice of modeling to solve real-world problems enables all students to understand and analyze key scientific and technical issues they will be asked to address throughout their lives. Communicating explanations coherently, with evidence from credible sources, is critical to engaging in public discourse.

Inclusion of science and engineering practices in standards only speak to the types of performances students should be able to demonstrate at the end of instruction of a particular course; the standards do not limit what educators and students should or can be engaged in through a well-rounded curriculum.

By the end of high school, students should have an understanding of and ability to apply each science and engineering practice to understand the world around them. Students should have had many opportunities to immerse themselves in the practices and to explore why they are central to the applications of science and engineering. Some examples of these science and engineering practices include:

1. 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.

2. Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

3. Plan and conduct an investigation, including deciding on the types, amount, and accuracy of data needed to produce reliable measurements, and consider limitations on the precision of the data.

4. Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific questions and engineering problems, using digital tools when feasible.

5. 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.

6. Apply scientific reasoning, theory, and/or models to link evidence to the claims and assess the extent to which the reasoning and data support the explanation or conclusion.

7. Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, and determining what additional information is required to solve contradictions.

8. Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media, verifying the data when possible.

While presented as distinct skill sets, the eight practices intentionally overlap and interconnect. Skills like those outlined above should be reflected in curriculum and instruction that engage students in an integrated use of the practices. The introductory courses (grades 9–10) integrate practices into the standards. In upper-level high school courses (grades 11–12), students should be given continued opportunities to develop the practices. See the Science and Engineering Practices Progression Matrix (Appendix I) for more information, including particular skills for students in high school.

High School Earth and Space Science

The high school Earth and space science standards build from middle school and allow grade 9 or 10 students to explain additional and more complex phenomena related to Earth processes and systems, interactions among Earth's systems, and interactions of Earth's systems and human actions. The standards expect students to apply a variety of science and engineering practices to three core ideas of earth and space science:

- The standards about **Earth's place in the universe** help students understand the universe and its stars, Earth and the solar system, and the history of planet Earth. Students examine the processes governing the formation, evolution, and workings of the solar system and universe.

- **Earth's systems** standards help students explain phenomena related to Earth materials and systems, plate tectonics and large-scale system interactions, the roles of water in Earth's surface processes, and weather and climate. Students develop models and explanations for the ways that feedbacks between different Earth systems control the appearance of Earth's surface. Central to this is the tension between internal systems, which are largely responsible for creating land at Earth's surface, and the Sun-driven surface systems that tear down the land through weathering and erosion. Students begin to examine the ways that human activities cause feedbacks that create changes to other systems. Students understand the system interactions that control weather and climate, with a major emphasis on the mechanisms and implications of climate change. Students model the flow of energy between different components of the weather system and chemical cycles such as the carbon cycle.

- Standards about **Earth and human activity** help students understand natural resources, natural hazards, human impact on Earth systems, and global climate change. Students understand the complex and significant interdependencies between humans and the rest of Earth's systems through the impacts of natural hazards, our dependencies on natural resources, and the significant environmental impacts of human activities. Students apply engineering design and the analysis of geoscience data to examine solutions to challenges facing long-term human sustainability on Earth.

Across the high school Earth and space science standards, particular emphasis is placed on **science and engineering practices** of developing and using models; constructing explanations; and obtaining, evaluating, and communicating information. For example, students are expected to be able to use models to describe and predict the relationships between Earth's systems and analyze data to support explanations of Earth processes. They must be able to construct and revise explanations based on valid, reliable, and relevant evidence and apply scientific reasoning to evaluate complex environmental problems such as the relationship between management of natural resources and sustainability or biodiversity. Students are expected to compare, synthesize, evaluate, and communicate information sources about various Earth systems, interactions between Earth and human activity, and the workings of the solar system. The application of these practices across the core ideas gives students a rich grounding in Earth and space science.

ESS1. Earth's Place in the Universe

HS-ESS1-1. Use informational text to explain that the life span of the Sun over approximately 10 billion years is a function of nuclear fusion in its core. Communicate that stars, through nuclear fusion over their life cycle, produce elements from helium to iron and release energy that eventually reaches Earth in the form of radiation.
State Assessment Boundary:
- Specific stages of the life of a star, details of the many different nucleosynthesis pathways for stars of differing masses, or calculations of energy released are not expected in state assessment.

HS-ESS1-2. Describe the astronomical evidence for the Big Bang theory, including the red shift of light from the motion of distant 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, which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).

HS-ESS1-4. Use Kepler's laws to predict the motion of orbiting objects in the solar system. Describe how orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.
Clarification Statements:
- Kepler's laws apply to human-made satellites as well as planets, moons, and other objects.
- Calculations involving Kepler's laws of orbital motions should not deal with more than two bodies, nor involve calculus.

HS-ESS1-5. Evaluate evidence of the past and current movements of continental and oceanic crust, the theory of plate tectonics, and relative densities of oceanic and continental rocks to explain why continental rocks are generally much older than rocks of the ocean floor.
Clarification Statement:
- Examples include the ages of oceanic crust (less than 200 million years old) increasing with distance from mid-ocean ridges (a result of plate spreading at divergent boundaries) and the ages of North American continental crust (which can be older than 4 billion years) increasing with distance away from a central ancient core (a result of past plate interactions at convergent boundaries).

[HS-ESS1-6 from NGSS is not included. HS-ESS1-3 from NGSS has been combined with HS-ESS1-1.]

ESS2. Earth's Systems

HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's hydrosphere can create feedbacks that cause changes to other Earth systems.
Clarification Statement:
- Examples can include how decreasing the amount of glacial ice reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice; how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; and how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.

HS-ESS2-3. Use a model based on evidence of Earth's interior to describe the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.

Clarification Statements:

- Emphasis is on both a two-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by gravity and thermal convection.
- Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.

HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems over different time scales result in changes in climate. Analyze and interpret data to explain that long-term changes in Earth's tilt and orbit result in cycles of climate change such as Ice Ages.

Clarification Statement:

- Examples of the causes of climate change differ by timescale: large volcanic eruption and ocean circulation over 1–10 years; changes in human activity, ocean circulation, and solar output over tens to hundreds of years; changes to Earth's orbit and the orientation of its axis over tens to hundreds of thousands of years; and long-term changes in atmospheric composition over tens to hundreds of millions of years.

State Assessment Boundary:

- Changes in climate will be limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution in state assessment.

HS-ESS2-5. Describe how the chemical and physical properties of water are important in mechanical and chemical mechanisms that affect Earth materials and surface processes.

Clarification Statements:

- Examples of mechanical mechanisms involving water include stream transportation and deposition, erosion using variations in soil moisture content, and frost wedging by the expansion of water as it freezes.
- Examples of chemical mechanisms involving water include chemical weathering and recrystallization (based on solubility of different materials) and melt generation (based on water lowering the melting temperature of most solids).

HS-ESS2-6. Use a model to describe cycling of carbon through the ocean, atmosphere, soil, and biosphere and how increases in carbon dioxide concentrations due to human activity have resulted in atmospheric and climate changes.

[HS-ESS2-1 has been merged with MS-ESS2-1. HS-ESS2-7 from NGSS is not included.]

ESS3. Earth and Human Activity

HS-ESS3-1. Construct an explanation based on evidence for how the availability of key natural resources and changes due to variations in climate have influenced human activity.

Clarification Statements:

- Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils (such as river deltas), high concentrations of minerals and fossil fuels, and biotic resources (such as fisheries and forests).
- Examples of changes due to variations in climate include changes to sea level and regional patterns of temperature and precipitation.

HS-ESS3-2. Evaluate competing design solutions for minimizing impacts of developing and using energy and mineral resources, and conserving and recycling those resources, based on economic, social, and environmental cost-benefit ratios.*
Clarification Statement:
- Examples include developing best practices for agricultural soil use, mining (for metals, coal, tar sands, and oil shales), and pumping (for petroleum and natural gas).

HS-ESS3-3. Illustrate relationships among management of natural resources, the sustainability of human populations, and biodiversity.
Clarification Statements:
- Examples of factors related to the management of natural resources include costs of resource extraction and waste management, per capita consumption, and the development of new technologies.
- Examples of factors related to human sustainability include agricultural efficiency, levels of conservation, and urban planning.
- Examples of factors related to biodiversity include habitat use and fragmentation, and land and resource conservation.

HS-ESS3-5. Analyze results from global climate models to describe how forecasts are made of the current rate of global or regional climate change and associated future impacts to Earth systems.
Clarification Statement:
- Climate model outputs include both climate changes (such as precipitation and temperature) and associated impacts (such as on sea level, glacial ice volumes, and atmosphere and ocean composition).

[HS-ESS3-4 and HS-ESS3-6 from NGSS is not included.]

High School Biology

The high school biology standards build from middle school and allow grade 9 or 10 students to explain additional and more complex phenomena related to genetics, the functioning of organisms, and interrelationships between organisms, populations, and the environment. The standards expect students to apply a variety of science and engineering practices to four core ideas of biology:

- **From molecules to organisms: structures and processes** standards help students formulate an answer to the question, "How do organisms live and grow?" Students demonstrate that they can use investigations and gather evidence to support explanations of cell function and reproduction. They understand the role of proteins as essential to the work of the cell and living systems. Students can use models to explain photosynthesis, respiration, and the cycling of matter and flow of energy in living organisms. The cellular processes can be used as a model for understanding the hierarchical organization of organisms.

- Standards focused on **ecosystems: interactions, energy, and dynamics** help students formulate an answer to the question, "How and why do organisms interact with their environment, and what are the effects of these interactions?" Students can use mathematical reasoning to demonstrate understanding of fundamental concepts of carrying capacity, factors affecting biodiversity and populations, and the cycling of matter and flow of energy among organisms in an ecosystem. These models support students' conceptual understanding of systems and their ability to develop design solutions to reduce the impact of human activities on the environment and maintain biodiversity.

- **Heredity: inheritance and variation of traits** standards help students formulate answers to the questions: "How are characteristics of one generation passed to the next? How can individuals of the same species and even siblings have different characteristics?" Students are able to ask questions, make and defend a claim, and use concepts of probability to explain the genetic variation in a population. Students demonstrate understanding of why individuals of the same species vary in how they look and function. Students can explain the mechanisms of genetic inheritance and describe the environmental and genetic causes of gene mutation and the alteration of gene expression.

- Standards for **biological evolution: unity and diversity** help students formulate an answer to the question, "What evidence shows that different species are related?" Students construct explanations for the processes of natural selection and evolution and communicate how multiple lines of evidence support these explanations. Students can evaluate evidence of the conditions that may result in new species and understand the role of genetic variation in natural selection. Additionally, students can apply concepts of probability to explain trends in populations as those trends relate to advantageous heritable traits in a specific environment.

The high school biology standards place particular emphasis on **science and engineering practices** of developing and using models; constructing explanations; engaging in argumentation from evidence; and obtaining, evaluating, and communicating information. Students are expected to use multiple types of models, including mathematical models, to make predictions and develop explanations, analyze and identify flaws in the model, and communicate ideas that accurately represent or simulate the biological system. Students are asked to construct and revise explanations and claims based on valid and reliable evidence and apply scientific reasoning to evaluate complex real-world problems such as the effects of human activity on biodiversity and ecosystem health. Students must be able to find and interpret scientific literature to compare, integrate, and evaluate sources and communicate phenomena related to genetics, the functioning of organisms, and interrelationships between organisms, populations, and the environment. The application of these practices across the core ideas gives students a rich grounding in biology.

LS1. From Molecules to Organisms: Structures and Processes

HS-LS1-1. Construct a model of transcription and translation to explain the roles of DNA and RNA that code for proteins that regulate and carry out essential functions of life.
Clarification Statements:
- Proteins that regulate and carry out essential functions of life include enzymes (which speed up chemical reactions), structural proteins (which provide structure and enable movement), and hormones and receptors (which send and receive signals).
- The model should show the double-stranded structure of DNA, including genes as part of DNA's transcribed strand, with complementary bases on the non-transcribed strand.
State Assessment Boundaries:
- Specific names of proteins or specific steps of transcription and translation are not expected in state assessment.
- Cell structures included in transcription and translation will be limited to nucleus, nuclear membrane, and ribosomes for state assessment.

HS-LS1-2. Develop and use a model to illustrate the key functions of animal body systems, including (a) food digestion, nutrient uptake, and transport through the body; (b) exchange of oxygen and carbon dioxide; (c) removal of wastes; and (d) regulation of body processes.
Clarification Statement:
- Emphasis is on the primary function of the following body systems (and structures): digestive (mouth, stomach, small intestine [villi], large intestine, pancreas), respiratory (lungs [alveoli], diaphragm), circulatory (heart, veins, arteries, capillaries), excretory (kidneys, liver, skin), and nervous (neurons, brain, spinal cord).
State Assessment Boundary:
- Chemical reactions in cells, details of particular structures (such as the structure of the neuron), or the identification of specific proteins in cells are not expected in state assessment.

HS-LS1-3. Provide evidence that homeostasis maintains internal body conditions through both body-wide feedback mechanisms and small-scale cellular processes.
Clarification Statements:
- Feedback mechanisms include the promotion of a stimulus through positive feedback (e.g., injured tissues releasing chemicals in blood that activate platelets to facilitate blood clotting), and the inhibition of stimulus through negative feedback (e.g., insulin reducing high blood glucose to normal levels).
- Cellular processes include (a) passive transport and active transport of materials across the cell membrane to maintain specific concentrations of water and other nutrients in the cell and (b) the role of lysosomes in recycling wastes, macromolecules, and cell parts into monomers.
State Assessment Boundary:
- Interactions at the molecular level (for example, how insulin is produced) are not expected in state assessment.

HS-LS1-4. Construct an explanation using evidence for why the cell cycle is necessary for the growth, maintenance, and repair of multicellular organisms. Model the major events of the cell cycle, including (a) cell growth and DNA replication, (b) separation of chromosomes (mitosis), and (c) separation of cell contents.
State Assessment Boundary:
- Specific gene control mechanisms or specific details of each event (e.g., phases of mitosis) are not expected in state assessment.

HS-LS1-5. Use a model to illustrate how photosynthesis uses light energy to transform water and carbon dioxide into oxygen and chemical energy stored in the bonds of sugars and other carbohydrates.

Clarification Statements:

- Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms.
- Examples of models could include diagrams, chemical equations, and conceptual models.

State Assessment Boundary:

- Specific biochemical steps of light reactions or the Calvin Cycle, or chemical structures of molecules are not expected in state assessment.

HS-LS1-6. Construct an explanation based on evidence that organic molecules are primarily composed of six elements, where carbon, hydrogen, and oxygen atoms may combine with nitrogen, sulfur, and phosphorus to form monomers that can further combine to form large carbon-based macromolecules.

Clarification Statements:

- Monomers include amino acids, mono- and disaccharides, nucleotides, and fatty acids.
- Organic macromolecules include proteins, carbohydrates (polysaccharides), nucleic acids, and lipids.

State Assessment Boundary:

- Details of specific chemical reactions or identification of specific macromolecule structures are not expected in state assessment.

HS-LS1-7. Use a model to illustrate that aerobic cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new bonds form, resulting in new compounds and a net transfer of energy.

Clarification Statements:

- Emphasis is on the conceptual understanding of the inputs and outputs of the process of aerobic cellular respiration.
- Examples of models could include diagrams, chemical equations, and conceptual models.
- The model should include the role of ATP for energy transfer in this process.
- Food molecules include sugars (carbohydrates), fats (lipids), and proteins.

State Assessment Boundary:

- Identification of the steps or specific processes involved in cellular respiration is not expected in state assessment.

LS2. Ecosystems: Interactions, Energy, and Dynamics

HS-LS2-1. Analyze data sets to support explanations that biotic and abiotic factors affect ecosystem carrying capacity.

Clarification Statements:

- Examples of biotic factors could include relationships among individuals (e.g., feeding relationships, symbioses, competition) and disease.
- Examples of abiotic factors could include climate and weather conditions, natural disasters, and availability of resources.
- Example data sets can be derived from simulations or historical data.

HS-LS2-2. Use mathematical representations to support explanations that biotic and abiotic factors affect biodiversity, including genetic diversity within a population and species diversity within an ecosystem.

Clarification Statements:

- Examples of biotic factors could include relationships among individuals (feeding relationships, symbiosis, competition) and disease.
- Examples of abiotic factors could include climate and weather conditions, natural disasters, and availability of resources.
- Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.

HS-LS2-4. Use a mathematical model to describe the transfer of energy from one trophic level to another. Explain how the inefficiency of energy transfer between trophic levels affects the relative number of organisms that can be supported at each trophic level and necessitates a constant input of energy from sunlight or inorganic compounds from the environment.

Clarification Statement:

- The model should illustrate the "10% rule" of energy transfer and show approximate amounts of available energy at each trophic level in an ecosystem (up to five trophic levels).

HS-LS2-5. Use a model that illustrates the roles of photosynthesis, cellular respiration, decomposition, and combustion to explain the cycling of carbon in its various forms among the biosphere, atmosphere, hydrosphere, and geosphere.

Clarification Statements:

- The primary forms of carbon include carbon dioxide, hydrocarbons, waste (dead organic matter), and biomass (organic materials of living organisms).
- Examples of models could include simulations and mathematical models.

State Assessment Boundary:

- The specific chemical steps of respiration, decomposition, and combustion are not expected in state assessment.

HS-LS2-6. Analyze data to show ecosystems tend to maintain relatively consistent numbers and types of organisms even when small changes in conditions occur but that extreme fluctuations in conditions may result in a new ecosystem. Construct an argument supported by evidence that ecosystems with greater biodiversity tend to have greater resistance to change and resilience.

Clarification Statement:

- Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption, fires, the decline or loss of a keystone species, climate changes, ocean acidification, or sea level rise.

HS-LS2-7. Analyze direct and indirect effects of human activities on biodiversity and ecosystem health, specifically habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, and climate change. Evaluate and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health.*

Clarification Statement:

- Examples of solutions can include captive breeding programs, habitat restoration, pollution mitigation, energy conservation, and ecotourism.

[HS-LS2-3 has been merged with HS-LS2-4 and HS-LS2-5. HS-LS2-8 from NGSS is not included.]

LS3. Heredity: Inheritance and Variation of Traits

HS-LS3-1. Develop and use a model to show how DNA in the form of chromosomes is passed from parents to offspring through the processes of meiosis and fertilization in sexual reproduction.
Clarification Statement:
- The model should demonstrate that an individual's characteristics (phenotype) result, in part, from interactions among the various proteins expressed by one's genes (genotype).

State Assessment Boundary:
- Identification of specific phases of meiosis or the biochemical mechanisms involved are not expected in state assessment.

HS-LS3-2. Make and defend a claim based on evidence that genetic variations (alleles) may result from (a) new genetic combinations via the processes of crossing over and random segregation of chromosomes during meiosis, (b) mutations that occur during replication, and/or (c) mutations caused by environmental factors. Recognize that mutations that occur in gametes can be passed to offspring.
Clarification Statement:
- Examples of evidence of genetic variation can include the work of McClintock in crossing over of maize chromosomes and the development of cancer due to DNA replication errors and UV ray exposure.

State Assessment Boundary:
- Specific phases of meiosis or identification of specific types of mutations are not expected in state assessment.

HS-LS3-3. Apply concepts of probability to represent possible genotype and phenotype combinations in offspring caused by different types of Mendelian inheritance patterns.
Clarification Statements:
- Representations can include Punnett squares, diagrams, pedigree charts, and simulations.
- Inheritance patterns include dominant-recessive, codominance, incomplete dominance, and sex-linked.

HS-LS3-4(MA). Use scientific information to illustrate that many traits of individuals, and the presence of specific alleles in a population, are due to interactions of genetic factors and environmental factors.
Clarification Statements:
- Examples of genetic factors include the presence of multiple alleles for one gene and multiple genes influencing a trait.
- An example of the role of the environment in expressed traits in an individual can include the likelihood of developing inherited diseases (e.g., heart disease, cancer) in relation to exposure to environmental toxins and lifestyle; an example in populations can include the maintenance of the allele for sickle-cell anemia in high frequency in malaria-affected regions because it confers partial resistance to malaria.

State Assessment Boundary:
- Hardy-Weinberg calculations are not expected in state assessment.

LS4. Biological Evolution: Unity and Diversity

HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence, including molecular, anatomical, and developmental similarities inherited from a common ancestor (homologies), seen through fossils and laboratory and field observations.
Clarification Statement:
- Examples of evidence can include the work of Margulis on endosymbiosis, examination of genomes, and analyses of vestigial or skeletal structures.

HS-LS4-2. Construct an explanation based on evidence that Darwin's theory of evolution by natural selection occurs in a population when the following conditions are met: (a) more offspring are produced than can be supported by the environment, (b) there is heritable variation among individuals, and (c) some of these variations lead to differential fitness among individuals as some individuals are better able to compete for limited resources than others.
  Clarification Statement:
  - Emphasis is on the overall result of an increase in the proportion of those individuals with advantageous heritable traits that are better able to survive and reproduce in the environment.

HS-LS4-4. Research and communicate information about key features of viruses and bacteria to explain their ability to adapt and reproduce in a wide variety of environments.
  Clarification Statement:
  - Key features include high rate of mutations and the speed of reproduction which produces many generations with high variability in a short time, allowing for rapid adaptation.
  State Assessment Boundary:
  - Specific types of viral reproduction (e.g., lytic and lysogenic) are not expected in state assessment.

HS-LS4-5. Evaluate models that demonstrate how changes in an environment may result in the evolution of a population of a given species, the emergence of new species over generations, or the extinction of other species due to the processes of genetic drift, gene flow, mutation, and natural selection.

[HS-LS4-3 from NGSS is merged with HS-LS4-2. HS-LS4-6 from NGSS is not included.]

High School Chemistry

The high school chemistry standards build from middle school physical sciences standards. Middle school includes an important transition from macroscopic phenomena to molecular level models that are used to explain and predict energy transformations in phase changes and conservation of matter in chemical changes, including the use of a basic particle model to visualize and represent physical changes of matter. In high school, students consider how structure and composition at sub-atomic scales explain structure-property relationships in chemistry and influence energy transformations and dissipation of energy during chemical and physical changes.

As a discipline that is concerned not only with what we can know but also with what we can do with what we know, chemistry emphasizes **science and engineering practices** related to design and evaluation as well as investigation and modeling. For example, students are challenged to apply chemistry knowledge to designing ways to control the extent of chemical reactions for practical purposes, analyze unknown samples to determine identities and concentrations of possible pollutants, and evaluate the consequences of using different materials for household items. Students are expected to apply mathematical reasoning when considering conservation of matter in chemical reactions and in comparing strength of acid-base solutions. Students apply a variety of science and engineering practices to three disciplinary core ideas of chemistry:

- The major focus of chemistry is on **matter and its interactions.** Students develop both molecular and sub-atomic models of matter and learn to rely on the periodic table as a powerful model for predicting a wide variety of properties of elements and compounds. Students develop greater capacity for building multi-step linear causal explanations by using a combination of the periodic table model and Coulomb's law to predict and explain qualitative comparisons of bond energies. They also consider spatial arrangements of ions in crystal structures and covalent bonds in molecules, and the relative favorability of energy changes required to rearrange components. Students reason about timescales in the context of a collision theory model, and consider how altering external conditions, chemical concentrations, and ways of introducing reactants to a system can be manipulated to control chemical processes. Students refine their understanding of conservation of matter by making quantitative predictions of theoretical yields if reactions are driven to completion using stoichiometric molar proportions and molar mass calculations. They also practice using two major models of reaction processes, the Bronsted-Lowry acid-base reaction model and the oxidation-reduction reaction model, to explain reaction patterns observed in many common phenomena in the natural world.

- Standards for **motion and stability: forces and interactions** help students explain structure-property relationships in terms of forces and interactions, and to consider the energetic stabilities of structures as a driving force in predicting a variety of observable response properties. Water's role as a common solvent is a central example in using molecular-level intermolecular bonding structure arguments to explain the relative solubilities of different ionic compounds. Intermolecular bonding is also explored in rationalizing why some classes of substances are better than others for specific practical uses, and designing molecular level structural specifications of substances that could have desired properties. Students also build on the basic particle model of matter studied in middle school to add quantitative predictions of externally controllable or measurable properties of gases.

- Standards about **energy** help students demonstrate understanding of energy transfer and dissipation of energy in chemical systems. Students rationalize observations of endothermic and exothermic changes in terms of energy required to break and form chemical bonds when structural rearrangements occur in chemical processes.

PS1. Matter and Its Interactions

HS-PS1-1. Use the periodic table as a model to predict the relative properties of main group elements, including ionization energy and relative sizes of atoms and ions, based on the patterns of electrons in the outermost energy level of each element. Use the patterns of valence electron configurations, core charge, and Coulomb's law to explain and predict general trends in ionization energies, relative sizes of atoms and ions, and reactivity of pure elements.
  Clarification Statement:
  • Size of ions should be relevant only for predicting strength of ionic bonding.
  State Assessment Boundary:
  • State assessment will be limited to main group (s and p block) elements.

HS-PS1-2. Use the periodic table model to predict and design simple reactions that result in two main classes of binary compounds, ionic and molecular. Develop an explanation based on given observational data and the electronegativity model about the relative strengths of ionic or covalent bonds.
  Clarification Statements:
  • Simple reactions include synthesis (combination), decomposition, single displacement, double displacement, and combustion.
  • Predictions of reactants and products can be represented using Lewis dot structures, chemical formulas, or physical models.
  • Observational data include that binary ionic substances (i.e., substances that have ionic bonds), when pure, are crystalline salts at room temperature (common examples include NaCl, KI, Fe_2O_3); and substances that are liquids and gases at room temperature are usually made of molecules that have covalent bonds (common examples include CO_2, N_2, CH_4, H_2O, C_8H_{18}).

HS-PS1-3. Cite evidence to relate physical properties of substances at the bulk scale to spatial arrangements, movement, and strength of electrostatic forces among ions, small molecules, or regions of large molecules in the substances. Make arguments to account for how compositional and structural differences in molecules result in different types of intermolecular or intramolecular interactions.
  Clarification Statements:
  • Substances include both pure substances in solid, liquid, gas, and networked forms (such as graphite).
  • Examples of bulk properties of substances to compare include melting point and boiling point, density, and vapor pressure.
  • Types of intermolecular interactions include dipole-dipole (including hydrogen bonding), ion-dipole, and dispersion forces.
  State Assessment Boundary:
  • Calculations of vapor pressure by Raoult's law, properties of heterogeneous mixtures, and names and bonding angles in molecular geometries are not expected in state assessment.

HS-PS1-4. Develop a model to illustrate the energy transferred during an exothermic or endothermic chemical reaction based on the bond energy difference between bonds broken (absorption of energy) and bonds formed (release of energy).
  Clarification Statement:
  • Examples of models may include molecular-level drawings and diagrams of reactions or graphs showing the relative energies of reactants and products.
  State Assessment Boundary:
  • Calculations using Hess's law are not expected in state assessment.

HS-PS1-5. Construct an explanation based on kinetic molecular theory for why varying conditions influence the rate of a chemical reaction or a dissolving process. Design and test ways to slow down or accelerate rates of processes (chemical reactions or dissolving) by altering various conditions.*

Clarification Statements:
- Explanations should be based on three variables in collision theory: (a) quantity of collisions per unit time, (b) molecular orientation on collision, and (c) energy input needed to induce atomic rearrangements.
- Conditions that affect these three variables include temperature, pressure, concentrations of reactants, agitation, particle size, surface area, and addition of a catalyst.

State Assessment Boundary:
- State assessment will be limited to simple reactions in which there are only two reactants and to specifying the change in only one variable at a time.

HS-PS1-6. Design ways to control the extent of a reaction at equilibrium (relative amount of products to reactants) by altering various conditions using Le Chatelier's principle. Make arguments based on kinetic molecular theory to account for how altering conditions would affect the forward and reverse rates of the reaction until a new equilibrium is established.*

Clarification Statements:
- Conditions that can be altered to affect the extent of a reaction include temperature, pressure, and concentrations of reactants.
- Conditions that can be altered to affect the rates of a reaction include temperature, pressure, concentrations of reactants, agitation, particle size, surface area, and addition of a catalyst.

State Assessment Boundaries:
- Calculations of equilibrium constants or concentrations are not expected in state assessment.
- State assessment will be limited to simple reactions in which there are only two reactants and to specifying the change in only one variable at a time.

HS-PS1-7. Use mathematical representations and provide experimental evidence to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. Use the mole concept and proportional relationships to evaluate the quantities (masses or moles) of specific reactants needed in order to obtain a specific amount of product.

Clarification Statements:
- Mathematical representations include balanced chemical equations that represent the laws of conservation of mass and constant composition (definite proportions), mass-to-mass stoichiometry, and calculations of percent yield.
- Evaluations may involve mass-to-mass stoichiometry and atom economy comparisons, but only for single-step reactions that do not involve complexes.

HS-PS1-9(MA). Relate the strength of an aqueous acidic or basic solution to the extent of an acid or base reacting with water as measured by the hydronium ion concentration (pH) of the solution. Make arguments about the relative strengths of two acids or bases with similar structure and composition.

Clarification Statements:
- Reactions are limited to Arrhenius and Bronsted-Lowry acid-base reaction patterns with monoprotic acids.
- Comparisons of relative strengths of aqueous acid or base solutions made from similar acid or base substances is limited to arguments based on periodic properties of elements, the electronegativity model of electron distribution, empirical dipole moments, and molecular geometry. Acid or base strength comparisons are limited to homologous series and should include dilution and evaporation of water.

HS-PS1-10(MA). Use an oxidation-reduction reaction model to predict products of reactions given the reactants, and to communicate the reaction models using a representation that shows electron transfer (redox). Use oxidation numbers to account for how electrons are redistributed in redox processes used in devices that generate electricity or systems that prevent corrosion.*
  Clarification Statement:
  - Reactions are limited to simple oxidation-reduction reactions that do not require hydronium or hydroxide ions to balance half-reactions.

HS-PS1-11(MA). Design strategies to identify and separate the components of a mixture based on relevant chemical and physical properties.
  Clarification Statements:
  - Emphasis is on compositional and structural features of components of the mixture.
  - Strategies can include chromatography, distillation, centrifuging, and precipitation reactions.
  - Relevant chemical and physical properties can include melting point, boiling point, conductivity, and density.

[HS-PS1-8 is found in introductory physics.]

PS2. Motion and Stability: Forces and Interactions

HS-PS2-6. Communicate scientific and technical information about the molecular-level structures of polymers, ionic compounds, acids and bases, and metals to justify why these are useful in the functioning of designed materials.*
  Clarification Statement:
  - Examples could include comparing molecules with simple molecular geometries; analyzing how pharmaceuticals are designed to interact with specific receptors; and considering why electrically conductive materials are often made of metal, household cleaning products often contain ionic compounds to make materials soluble in water, or materials that need to be flexible but durable are made up of polymers.
  State Assessment Boundary:
  - State assessment will be limited to comparing substances of the same type with one compositional or structural feature different.

HS-PS2-7(MA). Construct a model to explain how ions dissolve in polar solvents (particularly water). Analyze and compare solubility and conductivity data to determine the extent to which different ionic species dissolve.
  Clarification Statement:
  - Data for comparison should include different concentrations of solutions with the same ionic species, and similar ionic species dissolved in the same amount of water.

HS-PS2-8(MA). Use kinetic molecular theory to compare the strengths of electrostatic forces and the prevalence of interactions that occur between molecules in solids, liquids, and gases. Use the combined gas law to determine changes in pressure, volume, and temperature in gases.

[HS-PS2-1, HS-PS2-2, HS-PS2-3, HS-PS2-4, HS-PS2-5, HS-PS2-9(MA), and HS-PS2-10(MA) are found in introductory physics.]

PS3. Energy

HS-PS3-4b. Provide evidence from informational text or available data to illustrate that the transfer of energy during a chemical reaction in a closed system involves changes in energy dispersal (enthalpy change) and heat content (entropy change) while assuming the overall energy in the system is conserved.
  State Assessment Boundary:

- Calculations involving Gibbs free energy are not expected in state assessment.

[HS-PS3-1, HS-PS3-2, HS-PS3-3, HS-PS3-4a, and HS-PS3-5 are found in introductory physics.]

High School Introductory Physics

The high school introductory physics standards build from middle school and allow grade 9 or 10 students to explain additional and more complex phenomena central to the physical world. The standards expect students to apply a variety of science and engineering practices to three core ideas of physics:

- Standards on **motion and stability: forces and interactions** support students' understanding of ideas related to why some objects move in certain ways, why objects change their motion, and why some materials are attracted to each other while others are not. This core idea helps students answer the question, "How can one explain and predict interactions between objects and within systems of objects?" Students are able to demonstrate their understanding by applying scientific and engineering ideas related to Newton's second law, total momentum, conservation, system analysis, and gravitational and electrostatic forces.

- A focus on **energy** develops students' understanding of energy at both the macroscopic and atomic scales that can be accounted for as either motions of particles or energy stored in fields. This core idea helps students answer the question, "How is energy transferred and conserved?" Energy is understood as a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system; the total change of energy in any system is always equal to the total energy transferred into or out of the system. Students apply their understanding to explain situations that involve conservation of energy, energy transfer, and tracing the relationship between energy and forces.

- Standards on **waves and their applications in technologies for information transfer** support students' understanding of the physical principles used in a wide variety of existing and emerging technologies. As such, this core idea helps students answer the question, "How are waves used to transfer energy and send and store information?" Students are able to apply understanding of how wave properties and the interactions of electromagnetic radiation with matter can transfer information across long distances, store information, and investigate nature on many scales. They develop and use models of electromagnetic radiation, as either a wave of changing electric and magnetic fields or as particles. Students understand that combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. They can demonstrate their understanding by explaining how the principles of wave behavior and wave interactions with matter are used in technological devices to transmit and capture information and energy.

Across the set of high school introductory physics standards, particular emphasis is placed on **science and engineering practices** of developing and using models, analyzing and interpreting data, using mathematics, and engaging in argument from evidence. Students are expected to use mathematical and graphical representations and models to quantitatively and qualitatively describe, evaluate, and make predictions of a variety of phenomena such as motion, energy, and waves. Students should be able to use multiple types of models and compare their merits and limitations and level of detail and accuracy, and use them as a basis for explanations or arguments about underlying concepts or processes. The standards call for students to critique competing ideas and evaluate design solutions using data and evidence relevant to high school science. Analyzing and interpreting data gathered during investigations or experiments, such as of magnetic fields and electric current, wave properties, or motion, also contributes to students' development of explanations and arguments using relevant, quantitative evidence. Applying these practices across the core ideas gives students a rich grounding in introductory physics.

PS1. Matter and Its Interactions

HS-PS1-8. Develop a model to illustrate the energy released or absorbed during the processes of fission, fusion, and radioactive decay.
- Clarification Statements:
  - Examples of models include simple qualitative models, such as pictures or diagrams.
  - Types of radioactive decay include alpha, beta, and gamma.
- State Assessment Boundary:
  - Quantitative calculations of energy released or absorbed are not expected in state assessment.

[HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS1-4, HS-PS1-5, HS-PS1-6, and HS-PS1-7 are found in chemistry.]

PS2. Motion and Stability: Forces and Interactions

HS-PS2-1. Analyze data to support the claim that Newton's second law of motion is a mathematical model describing change in motion (the acceleration) of objects when acted on by a net force.
- Clarification Statements:
  - Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, and a moving object being pulled by a constant force.
  - Forces can include contact forces, including friction, and forces acting at a distance, such as gravity and magnetic forces.
- State Assessment Boundary:
  - Variable forces are not expected in state assessment.

HS-PS2-2. Use mathematical representations to show that the total momentum of a system of interacting objects is conserved when there is no net force on the system.
- Clarification Statement:
  - Emphasis is on the qualitative meaning of the conservation of momentum and the quantitative understanding of the conservation of linear momentum in interactions involving elastic and inelastic collisions between two objects in one dimension.

HS-PS2-3. Apply scientific principles of motion and momentum to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*
- Clarification Statement:
  - Both qualitative evaluations and algebraic manipulations may be used.

HS-PS2-4. Use mathematical representations of Newton's law of gravitation and Coulomb's law to both qualitatively and quantitatively describe and predict the effects of gravitational and electrostatic forces between objects.
- Clarification Statement:
  - Emphasis is on the relative changes when distance, mass or charge, or both are changed.
- State Assessment Boundaries:
  - State assessment will be limited to systems with two objects.
  - Permittivity of free space is not expected in state assessment.

HS-PS2-5. Provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
- Clarification Statement:
  - Examples of evidence can include movement of a magnetic compass when placed in the vicinity of a current-carrying wire, and a magnet passing through a coil that turns on the light of a Faraday flashlight.
- State Assessment Boundary:
  - Explanations of motors or generators are not expected in state assessment.

HS-PS2-9(MA). Evaluate simple series and parallel circuits to predict changes to voltage, current, or resistance when simple changes are made to a circuit.

Clarification Statements:

- Predictions of changes can be represented numerically, graphically, or algebraically using Ohm's law.
- Simple changes to a circuit may include adding a component, changing the resistance of a load, and adding a parallel path, in circuits with batteries and common loads.
- Simple circuits can be represented in schematic diagrams.

State Assessment Boundary:

- Use of measurement devices and predictions of changes in power are not expected in state assessment.

HS-PS2-10(MA). Use free-body force diagrams, algebraic expressions, and Newton's laws of motion to predict changes to velocity and acceleration for an object moving in one dimension in various situations.

Clarification Statements:

- Predictions of changes in motion can be made numerically, graphically, and algebraically using basic equations for velocity, constant acceleration, and Newton's first and second laws.
- Forces can include contact forces, including friction, and forces acting at a distance, such as gravity and magnetic forces.

[HS-PS2-6, HS-PS2-7(MA), and HS-PS2-8(MA) are found in chemistry.]

PS3. Energy

HS-PS3-1. Use algebraic expressions and the principle of energy conservation to calculate the change in energy of one component of a system when the change in energy of the other component(s) of the system, as well as the total energy of the system including any energy entering or leaving the system, is known. Identify any transformations from one form of energy to another, including thermal, kinetic, gravitational, magnetic, or electrical energy, in the system.

Clarification Statement:

- Systems should be limited to two or three components and to thermal energy; kinetic energy; or the energies in gravitational, magnetic, or electric fields.

HS-PS3-2. Develop and use a model to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles and objects or energy stored in fields.

Clarification Statements:

- Examples of phenomena at the macroscopic scale could include evaporation and condensation, the conversion of kinetic energy to thermal energy, the gravitational potential energy stored due to position of an object above the earth, and the stored energy (electrical potential) of a charged object's position within an electrical field.
- Examples of models could include diagrams, drawings, descriptions, and computer simulations.

HS-PS3-3. Design and evaluate a device that works within given constraints to convert one form of energy into another form of energy.*

Clarification Statements:

- Emphasis is on both qualitative and quantitative evaluations of devices.
- Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators.
- Examples of constraints could include use of renewable energy forms and efficiency.

State Assessment Boundary:

- Quantitative evaluations will be limited to total output for a given input in state assessment.

HS-PS3-4a. Provide evidence that when two objects of different temperature are in thermal contact within a closed system, the transfer of thermal energy from higher-temperature objects to lower-temperature objects results in thermal equilibrium, or a more uniform energy distribution among the objects and that temperature changes necessary to achieve thermal equilibrium depend on the specific heat values of the two substances.

Clarification Statement:
- Energy changes should be described both quantitatively in a single phase $(Q = mc\Delta T)$ and conceptually either in a single phase or during a phase change.

HS-PS3-5. Develop and use a model of magnetic or electric fields to illustrate the forces and changes in energy between two magnetically or electrically charged objects changing relative position in a magnetic or electric field, respectively.

Clarification Statements:
- Emphasis is on the change in force and energy as objects move relative to each other.
- Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.

[HS-PS3-4b is found in chemistry.]

PS4. Waves and Their Applications in Technologies for Information Transfer

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling within various media. Recognize that electromagnetic waves can travel through empty space (without a medium) as compared to mechanical waves that require a medium.

Clarification Statements:
- Emphasis is on relationships when waves travel within a medium, and comparisons when a wave travels in different media.
- Examples of situations to consider 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 include $v = \lambda f$, $T = 1/f$, and the qualitative comparison of the speed of a transverse (including electromagnetic) or longitudinal mechanical wave in a solid, liquid, gas, or vacuum.

State Assessment Boundary:
- Transitions between two media are not expected in state assessment.

HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described by either a wave model or a particle model, and that for some situations involving resonance, interference, diffraction, refraction, or the photoelectric effect, one model is more useful than the other.

Clarification Statement:
- Emphasis is on qualitative reasoning and comparisons of the two models.

State Assessment Boundary:
- Calculations of energy levels or resonant frequencies are not expected in state assessment.

HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*

Clarification Statements:
- Emphasis is on qualitative information and descriptions.

- Examples of technological devices could include solar cells capturing light and converting it to electricity, medical imaging, and communications technology.
- Examples of principles of wave behavior include resonance, photoelectric effect, and constructive and destructive interference.

State Assessment Boundary:
- Band theory is not expected in state assessment.

[HS-PS4-2 and HS-PS4-4 from NGSS are not included.]

High School Technology/Engineering

The high school technology/engineering standards build from middle school and allow grade 9 or 10 students to explain major technological systems used in society and to engage in more sophisticated design problems. The standards expect students to apply a variety of science and engineering practices to four core ideas of technology/engineering:

- **Engineering design** standards support students' understanding of how engineering design is applied to complex societal challenges as well as developing their skills in defining design problems and developing solutions.

- A focus on **materials, tools, and manufacturing** supports students in understanding how manufacturing makes use of and can change material properties to create useful products. They consider different manufacturing processes, including where computer-aided systems can be useful, and how those processes can affect material properties.

- Standards about **technological systems** help students to learn how complex design systems work, particularly those they use every day. Such systems include communications systems, structural systems, and transportation systems. Through the study of these critical infrastructure systems, students understand how the components they interact with every day depend on the design and functioning of the larger system. They also can abstract the concept of a system, identifying inputs and outputs of subsystems and their interrelationships.

- **Energy and power technologies** standards support students in understanding how humans manipulate and use energy to accomplish physical tasks that would otherwise be impossible or difficult. These technologies include open and closed pneumatic and hydraulic systems.

The high school technology/engineering standards place particular emphasis on **science and engineering practices** of developing and using models; analyzing and interpreting data; using mathematics; designing solutions; and obtaining, evaluating, and communicating information. Relevant examples give students a valuable context to learn about and model a technological system, use a model to explain differences in systems or illustrate how a system works. This leads to a more detailed understanding of the role that engineering design, materials, tools, and manufacturing have in the natural and designed world. The standards expect students to research and analyze specific design solutions that give them an opportunity to determine optimal conditions for performance of materials, influences of cost, constraints, criteria, and possible environmental impacts. Use of mathematics is a key skill in designing prototypes to scale, using prototypes or simulations that model multiple interactions in a complex problem and calculating change to a system that includes a number of variables. Students communicate and evaluate solutions to real-world problems, propose or refine solutions, and examine the social and cultural impacts a product, material, manufacturing process, or technology could have in our world. The application of these practices across the core ideas gives students a rich grounding in technology/engineering.

ETS1. Engineering Design

HS-ETS1-1. Analyze a major global challenge to specify a design problem that can be improved. Determine necessary qualitative and quantitative criteria and constraints for solutions, including any requirements set by society.*
Clarification Statement:
- Examples of societal requirements can include risk mitigation, aesthetics, ethical considerations, and long-term maintenance costs.

HS-ETS1-2. Break a complex real-world problem into smaller, more manageable problems that each can be solved using scientific and engineering principles.*

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, aesthetics, and maintenance, as well as social, cultural, and environmental impacts.*

HS-ETS1-4. Use a computer simulation to model the impact of a proposed solution to a complex real-world problem that has numerous criteria and constraints on the interactions within and between systems relevant to the problem.*

HS-ETS1-5(MA). Plan a prototype or design solution using orthographic projections and isometric drawings, using proper scales and proportions.*

HS-ETS1-6(MA). Document and present solutions that include specifications, performance results, successes and remaining issues, and limitations.*

ETS2. Materials, Tools, and Manufacturing

HS-ETS2-1(MA). Determine the best application of manufacturing processes to create parts of desired shape, size, and finish based on available resources and safety.
Clarification Statement:
- Examples of processes can include forming (molding of plastics, casting of metals, shaping, rolling, forging, and stamping), machining (cutting and milling), conditioning (thermal, mechanical, and chemical processes), and finishing.

State Assessment Boundary:
- Specific manufacturing machines are not expected in state assessment.

HS-ETS2-2(MA). Explain how computers and robots can be used at different stages of a manufacturing system, typically for jobs that are repetitive, very small, or very dangerous.
Clarification Statement:
- Examples of stages include design, testing, production, and quality control.

HS-ETS2-3(MA). Compare the costs and benefits of custom versus mass production based on qualities of the desired product, the cost of each unit to produce, and the number of units needed.

HS-ETS2-4(MA). Explain how manufacturing processes transform material properties to meet a specified purpose or function. Recognize that new materials can be synthesized through chemical and physical processes that are designed to manipulate material properties to meet a desired performance condition.
Clarification Statement:
- Examples of material properties can include resistance to force, density, hardness, and elasticity.

ETS3. Technological Systems

HS-ETS3-1(MA). Model a technological system in which the output of one subsystem becomes the input to other subsystems.

HS-ETS3-2(MA). Use a model to explain how information transmitted via digital and analog signals travels through the following media: electrical wire, optical fiber, air, and space. Analyze a communication problem and determine the best mode of delivery for the communication(s).

HS-ETS3-3(MA). Explain the importance of considering both live loads and dead loads when constructing structures. Calculate the resultant force(s) for a combination of live loads and dead loads for various situations.
Clarification Statements:
- Examples of structures can include buildings, decks, and bridges.
- Examples of loads and forces include live load, dead load, total load, tension, sheer, compression, and torsion.

HS-ETS3-4(MA). Use a model to illustrate how the forces of tension, compression, torsion, and shear affect the performance of a structure. Analyze situations that involve these forces and justify the selection of materials for the given situation based on their properties.
Clarification Statements:
- Examples of structures include bridges, houses, and skyscrapers.
- Examples of material properties can include elasticity, plasticity, thermal conductivity, density, and resistance to force.

HS-ETS3-5(MA). Analyze how the design of a building is influenced by thermal conditions such as wind, solar angle, and temperature. Give examples of how conduction, convection, and radiation are considered in the selection of materials for buildings and in the design of a heating system.

HS-ETS3-6(MA). Use informational text to illustrate how a vehicle or device can be modified to produce a change in lift, drag, friction, thrust, and weight.
Clarification Statements:
- Examples of vehicles can include cars, boats, airplanes, and rockets.
- Considerations of lift require consideration of Bernoulli's principle.

ETS4. Energy and Power Technologies

HS-ETS4-1(MA). Research and describe various ways that humans use energy and power systems to harness resources to accomplish tasks effectively and efficiently.
Clarification Statement:
- Examples of energy and power systems can include fluid systems such as hydraulics and pneumatics, thermal systems such as heating and cooling, and electrical systems such as electronic devices and residential wiring.

HS-ETS4-2(MA). Use a model to explain differences between open fluid systems and closed fluid systems. Determine when it is more or less appropriate to use one type of system instead of the other.
Clarification Statements:
- Examples of open systems can include irrigation, forced hot air systems, and air compressors.
- Examples of closed systems can include forced hot water systems and hydraulic brakes.

HS-ETS4-3(MA). Explain how differences and similarities between hydraulic and pneumatic systems lead to different applications of each in technologies.

HS-ETS4-4(MA). Calculate and describe the ability of a hydraulic system to multiply distance, multiply force, and effect directional change.
Clarification Statement:

- Emphasis is on the ratio of piston sizes (cross-sectional area) as represented in Pascal's law.

HS-ETS4-5(MA). Explain how a machine converts energy, through mechanical means, to do work. Collect and analyze data to determine the efficiency of simple and complex