Utah Science with Engineering Education (SEEd) Standards

Kindergarten through 5th Grade Integrated Science, Biology, Chemistry, Earth and Space Science, and Physics

Draft for Public Review – January 2019

Overview

In December 2015, the Utah State Board of Education (USBE) adopted Utah Science with Engineering Education (SEEd) Standards for grades 6-8. In April 2018, the USBE accepted the Science Standards Review Committee Report and recommended that K-5 and High School Science Standards Writing Teams be organized to complete the standards update from Kindergarten to High School (K-12). Writing teams, consisting of Utah university professors and Utah K-12 science teachers, first met in May 2018 and their work continued through November 2018.

With approval from the USBE, this draft of the Utah K-5/9-12 SEEd Standards is available for public review and feedback. To provide feedback on the draft an online public feedback survey tool is available and there will be six public hearings where USBE staff will collect feedback directly from the public. The online survey is currently open and scheduled to close on April 11, 2019 at 11:45pm.

Link to Online Public Feedback Survey: surveymonkey.com/r/UTSEEd90DayReview

Public Hearings:
Details for the Public Hearings are found on the USBE Science Website - www.schools.utah.gov/curr/science

Once the 90-Day Public Review has concluded, the science writing teams will reconvene, review feedback, and finalize an updated draft for the USBE to review.

Thank you for taking time to provide your feedback and supporting the process of developing science standards that prepare Utah students to be science literate and college and career ready.

Supporting Documentation

As directed by the Science Standards Review Committee and approved by the USBE, the standards writing teams used the Next Generation Science Standards (NGSS) as a starting document for the draft standards. A crosswalk to show alignments between current Utah Science Standards, Draft Utah SEEd Standards, and NGSS Standards was created.

SEEd Standards Crosswalk Document: tinyurl.com/SEEdCrosswalk

Standards writing teams were directed to create a document that described their thinking and justification for the standards draft. They were asked to track what standards document (NGSS, other state standards) were used in the creation of the Utah Standard and to describe the changes that were made. Every team created their own document to track these changes so they each appear different from each other.

- tinyurl.com/SEEdK2Doc - Kindergarten through 2nd Grade Team Supporting Documentation
- tinyurl.com/SEEd35Doc - 3rd Grade through 5th Grade Team Supporting Documentation
- tinyurl.com/SEEdHSDoc - High School Team Supporting Documentation

INTRODUCTION | KINDERGARTEN

Science Literacy for All Students

Science is a way of knowing, a process for gaining knowledge and understanding of the natural world. Engineering combines the fields of science, technology, and mathematics to provide solutions to real-world problems. The nature and process of developing scientific knowledge and understanding includes constant questioning, testing, and refinement, which must be supported by evidence and has little to do with popular consensus. Since progress in the modern world is tied so closely to this way of knowing, scientific literacy is essential for a society to be competitively engaged in a global economy. Students should be active learners who demonstrate their scientific understanding by using it. It is not enough for students to read about science; they must participate in the three dimensions of science. They should observe, inquire, question, formulate and test hypotheses, analyze data, report, and evaluate findings. The students, as scientists, should have hands-on, active experiences throughout the instruction of the science curriculum. These standards help students find value in developing novel solutions as they engage with complex problems.

Three Dimensions of Science[1]

Science education includes three dimensions of science understanding: science and engineering practices, crosscutting concepts, and disciplinary core ideas. Every standard includes each of the three dimensions; **Science and Engineering Practices are bolded**, <u>Crosscutting Concepts are underlined</u>, and Disciplinary Core Ideas are in normal font. Standards with *specific engineering expectations are italicized*.

Science and Engineering Practices	<u>Crosscutting Concepts</u>	Disciplinary Core Ideas
◗ Asking questions or defining problems ◗ Developing and using models ◗ Planning and carrying out investigations ◗ Analyzing and interpreting data ◗ Using mathematics and computational thinking ◗ Constructing explanations and designing solutions ◗ Engaging in argument from Evidence ◗ Obtaining, evaluating, and communicating information	◗ Patterns ◗ Cause and effect: mechanism and explanation ◗ Scale, proportion, and Quantity ◗ Systems and system models ◗ Energy and matter: flows, cycles, and conservation ◗ Structure and function ◗ Stability and change	◗ Earth and Space Science ◗ Life Science ◗ Physical Science ◗ Engineering

[1] NRC Framework K–12 Science Education: http://www.nap.edu/catalog.php?record_id=13165

Organization of Standards

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Kindergarten |
Utah Science with Engineering Education (SEEd) Standards

The Kindergarten SEEd standards provide a framework for students to obtain, evaluate, and communicate how the sun causes our weather patterns and how these patterns affect living systems. Students will also investigate how design solutions can manipulate the effect of sunlight. Additionally, students are introduced to the concept of forces through push and pull interactions only.

Strand K.1: WEATHER PATTERNS

Weather is caused by unequal heating of the Earth's surfaces resulting in temperature differences, wind, and seasonal precipitation, in a particular region. Observing, measuring and recording these conditions can discover weather patterns used in forecasting. Weather scientists forecast weather so that communities can prepare for and respond to local weather.

■ **Standard K.1.1** **Obtain, evaluate, and communicate information** about local, observable weather conditions to describe patterns over time. Emphasize the students' collection and sharing of data about temperature, wind, and precipitation, including the changes from day to day and season to season. Examples could include data collected through personal observations, the use of tools such as thermometers, windsocks, and rain gauges.

■ **Standard K.1.2** **Obtain, evaluate, and communicate information** on how weather patterns affect human behavior. Examples of local severe weather could include extreme heat, high winds, flash floods, thunderstorms, and snowstorms.

■ **Standard K.1.3** **Carry out an investigation**, making observations, to determine the effect of sunlight energy on Earth's surfaces. An example could include measuring temperature through touch, using thermometers, or other methods, in various locations or on different materials throughout the day.

■ **Standard K.1.4** ***Design*** *and construct* **a solution** that will reduce the warming effect of sunlight on an area. Emphasize the use of tools and materials to test and build a structure. Examples of structures could include umbrellas, canopies, and tents.

Strand K.2: MATTER, ENERGY, AND LIFE

Living things need matter and energy to survive. Water and other resources, such as food, provide the necessary matter for survival. Plants obtain energy through sunlight while animals obtain energy from other living things. The environment can be changed due to the presence of plants and animals.

■ **Standard K.2.1** **Analyze and interpret data** to describe <u>patterns</u> of what plants and animals (including humans) need to survive. Emphasize the similarities and differences between the survival needs of all living things (plants and animals). Examples could include that many plants do not consume food, but animals do; plants acquire water through roots, while many animals drink water.

■ **Standard K.2.2** **Obtain, evaluate, and communicate information** about <u>patterns</u> in the relationships between the needs of different living things and the places they live. Emphasize that living things (plants and animals) need water, air, and resources and they live in places that have the things they need. Examples could include growing plants in various locations and comparing the results or comparing animals and the places they live.

■ **Standard K.2.3** **Obtain, evaluate, and communicate information** about how plants and animals (including humans) <u>affect</u> their environment in order to survive. Examples could include a squirrel digging in the ground to hide their food, plant roots breaking concrete, or humans using a tent while camping.

■ **Standard K.2.4** **Plan and carry out an investigation** about the <u>cause and effect</u> relationship that living things have with land, water, and air resources. Then *design and communicate* solutions to potential problems. Examples could include how to remove ice from a shady area, how to supply water to dry areas, or how to remove debris from habitat.

Strand K.3: FORCES AND INTERACTIONS

Forces can be described as pushes and pulls, which can have different strengths or different directions. Pushing or pulling on an object can change the direction of its motion and can start or stop it.

■ **Standard K.3.1** **Plan and conduct an investigation** to compare the effects of different strengths or different directions of forces (pushes and pulls) on the motion of an object. When teaching the concept of push and pull, the idea of strength should be kept separate from the idea of direction and should not include non-contact forces (magnets).

■ **Standard K.3.2** ***Analyze data*** to *determine how a design solution* causes a change in the speed or direction of an object with a push or a pull. Examples of problems requiring a solution could include having a marble or other object move a certain distance, follow a particular path, or knock down other objects. Examples of solutions could include tools, such as a ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn.

INTRODUCTION | GRADE 1

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Grade One |
Utah Science with Engineering Education (SEEd) Standards

The First grade SEEd standards provide a framework for students to explore seasonal patterns through observing the movement of the sun, moon, and stars. The effect of these seasonal patterns can be found through researching the external features of plants and animals and the behavior of animals. The initial concept of heredity is introduced through the simple idea these same features are passed from parent to offspring. Additionally, students are introduced to the interaction of light and sound energy with matter. This content will build on their understanding from Kindergarten, as well as prepare them for future learning.

Strand 1.1: SEASONS AND SPACE PATTERNS

Seasonal patterns of motion of the sun, moon, and stars can be observed, described, and predicted. These patterns may vary depending on the region, location, or time of year. These patterns have effects on living and nonliving things on Earth, to which humans may need to find solutions.

■ **Standard 1.1.1** **Obtain, evaluate, and communicate information** on the movement of the sun, moon, and stars to describe patterns that can be predicted. Examples of patterns could include how the sun and moon appear to rise in one part of the sky, move across the sky, and set; and stars other than the sun are visible at night but not during the day.

■ **Standard 1.1.2** **Obtain, evaluate, and communicate** the patterns observed at different times of the year in order to relate the amount of daylight to the time of year. Emphasize the variation in daylight patterns at different times of the day and different times of the year. Examples could include varying locations and regions throughout the state, country and world.

■ **Standard 1.1.3** ***Design a solution*** and *construct a tool* that uses the varying patterns of daylight to solve a problem. Examples could include sundials for telling the time, solar ovens for cooking, or a greenhouse for growing plants.

Strand 1.2: THE NEEDS OF LIVING THINGS AND THEIR OFFSPRING

Living things need matter and energy to survive. Plants and animals have external features that allow them to survive in a variety of environments. Young animals and plants are similar, but not exactly like their parents. In many kinds of animals, parents and offspring engage in behaviors that help the offspring to survive.

■ **Standard 1.2.1** **Plan and conduct an investigation** to identify the basic needs of plants. Emphasize how removal of a resource to meet a basic need may have an effect on its survival.

■ **Standard 1.2.2** **Construct an explanation,** by observing patterns of external features, about how living things (plants and animals) survive in different environments. Emphasize how living things, found in specific environments, share similar physical characteristics. Examples include ways plants and animals conserve water in desert environments, or ways plants and animals conserve heat and energy in cold environments.

■ **Standard 1.2.3** **Obtain, evaluate, and communicate** the patterns of how living things (plants and animals) are alike, but not exactly like, their parents. Examples could include fur color on dogs, or flower color and/or leaf shape of plants.

■ **Standard 1.2.4** **Construct an explanation** using text and media of the patterns in the behaviors of parents and offspring which help offspring to survive. Examples of patterns of behaviors could include the signals that offspring make (such as crying, chirping, and other vocalizations) and the responses of the parents (such as feeding, comforting and protecting the offspring).

Strand 1.3: LIGHT AND SOUND

Sound can make matter vibrate and vibrating matter can make sound. Objects can only be seen when light is available to illuminate them. Some objects give off their own light. Some materials allow light to pass through them, others allow only some light to pass through them, and still others block light and create a dark shadow on the surface beyond them, where the light cannot reach. Mirrors can be used to redirect light. People use a variety of devices that may include sound and light to communicate over long distances.

- **Standard 1.3.1** **Plan and conduct an investigation** to show the cause and effect relationship between sound and vibrating matter. Emphasize that vibrating matter can make sound and that sound can make matter vibrate and that sound is energy.

- **Standard 1.3.2** **Use a model** to show that objects can be seen when light is available to illuminate them or if they give off their own light. Emphasize the cause and effect relationship between light and objects, and that light is energy.

- **Standard 1.3.3** **Plan and conduct an investigation** to determine the effect of materials in the path of a beam of light. Emphasize that light can travel through some materials, can be reflected off some materials, and some materials block light causing shadows. Examples of materials could include those that are transparent (such as clear plastic), translucent (such as wax paper), opaque (such as cardboard), and reflective (such as a mirror).

- **Standard 1.3.4** ***Design*** and *build a device* whose structure uses light or sound to solve the problem of communicating over a distance. Examples of devices could include a light source to send signals, paper cup and string "telephones", and a pattern of drum beats.

INTRODUCTION | GRADE 2

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Grade Two |

Utah Science with Engineering Education (SEEd) Standards

The Second grade SEEd standards provide a framework that introduces the concept of matter through using patterns to classify different properties and characteristics. These strands also emphasize the changing and restructuring of matter through the lens of geologic events, specifically those dealing with wind and water. Different habitats are caused by varied amounts of water, types of food, and other resources present. By researching the physical appearance/characteristics and behaviors of living things, students will understand how habitat types influence these characteristics and their functions.

Strand 2.1: CHANGES IN EARTH'S SURFACE

The Earth has an ancient history of slow and gradual surface changes, punctuated with quick but powerful geologic events, like volcanic eruptions, flooding, and earthquakes. Water plays a significant role in changing the surface of Earth and can be found in the wind, and in liquid and solid forms. The effects of wind and water can cause both slow and quick changes to the surface of the Earth.

- **Standard 2.1.1** **Construct an explanation** about the cause and effect of changes in the Earth's surface that happen quickly or slowly. Emphasize the contrast between volcanic eruptions, flooding, and earthquakes that happen quickly to the slow erosion of rocks.

- **Standard 2.1.2** **Design** *and analyze* **solutions** to slow or prevent wind or water from changing the shape of land. Examples of solutions could include dikes, windbreaks, shrubs, trees, and grass to hold back wind, water, and land.

- **Standard 2.1.3** **Develop and use models** illustrating the patterns of landforms and water on Earth. The model could depict water in the solid or liquid state. Examples could include a mountain with a glacier, a stream feeding into a lake, a bay environment, or an ocean surrounding a continent.

Strand 2.2: LIVING THINGS AND THEIR HABITATS

Living things need water, air, and resources from the land to survive and they live in habitats that provide these necessities. The physical characteristics of plants and animals reflect the habitat in which they live. Plants have unique structures (roots, stems, leaves, flowers, and fruit/seeds) that help them survive in their habitats. Animals also have modified behaviors that help them survive, grow, and meet their needs. Humans sometimes mimic plant and animal adaptations to survive in their environment.

■ **Standard 2.2.1** **Obtain, evaluate, and communicate information** about <u>patterns</u> of climate and resources in different habitats. Examples of different habitats could include descriptions of temperature, precipitation, and types of plants and animals.

■ **Standard 2.2.2** **Plan and carry out an investigation** of the <u>structure and function</u> of plant and animal parts to compare the diversity of life in different habitats. Examples could include how different plants and animals have different structures to survive in their habitat, such as the spines of a cactus in the desert or the seasonal changes in the fur coat of a wolf.

■ **Standard 2.2.3** **Develop and use a model** mimicking the <u>function</u> of an animal dispersing seeds or pollinating plants.

■ **Standard 2.2.4** ***Design a solution*** to a human problem by mimicking the <u>structure and function</u> of plants and/or animals and how they use their external parts to help them survive, grow, and meet their needs. Examples could include a human wearing a jacket to mimic the fur of an animal, or sucking water through a straw to mimic the roots of a tree.

Strand 2.3: PROPERTIES OF MATTER

All things are made of matter which exists in different forms (solid, liquid, or gas) depending on temperature. Heating or cooling some types of matter can irreversibly change their properties. Matter can be described and classified by its observable properties (e.g., strength, flexibility, hardness, texture, ability to absorb). Materials with certain properties are well-suited for specific uses.

- **Standard 2.3.1** **Plan and carry out an investigation** to classify different kinds of materials based on patterns of their observable properties. Examples could include sorting materials based on similar properties, such as strength, color, flexibility, hardness, texture, etc.

- **Standard 2.3.2** **Construct explanations** for how the properties of materials influence their function and intended uses. Emphasize that materials are used for different reasons because of their properties.

- **Standard 2.3.3** **Plan and carry out an investigation** of how an object, made of a small set pieces, can be disassembled and reshaped into a new object with a different function. Examples of pieces could include blocks, building bricks, or other assorted small objects.

- **Standard 2.3.4** **Observe, obtain and communicate information** about how energy influences change in matter through heating and cooling. Some of these changes can be reversed and some cannot. Examples of reversible changes could be freezing or boiling water and melting crayons. Examples of irreversible changes could include cooking an egg, freezing a plant leaf, and burning wood.

INTRODUCTION | GRADE 3

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Grade Three |
Utah Science with Engineering Education (SEEd) Standards

The third grade SEEd standards provide a framework for student understanding of phenomena in earth, life, and physical science using the lens of cause and effect. Students will analyze data of weather conditions to build an understanding of climate patterns in different regions of the world. Using their understanding of weather and climate, students will design solutions to minimize the effects of weather-related hazards. Students will also analyze data and develop models to explain how traits are inherited from parents and influenced by the environment. Students will develop explanations for how organisms' traits can affects their ability to survive in particular environments. Students will design solutions to problems caused by changes in an environment. Students will continue to use the lens of cause and effect to explore the relationships between force and motion. Students will investigate the forces that objects exert on each other, gravitational, electric, and magnetic forces and how these forces affect motion. Through investigating weather, traits, and forces students will expand their understanding of cause and effect relationships in the natural and designed world.

Strand 3.1: WEATHER AND CLIMATE PATTERNS

Weather is a minute-by-minute, day-by-day variation of the atmosphere's condition on a local scale. Scientists record patterns of weather across different times and areas so that they can make weather forecasts. Climate describes the ranges of an area's typical weather conditions and the extent to which those conditions vary over decades. Severe weather can impact humans in a variety of ways. While humans can not eliminate severe weather, they can design solutions to reduce its impact.

■ **Standard 3.1.1** **Analyze and interpret data** to reveal <u>patterns</u> that indicate typical weather conditions expected during a particular season. Examples of data could include average temperature, precipitation, or wind direction. Emphasize representing data in tables and graphs.

■ **Standard 3.1.2** **Obtain and communicate information** to describe climate <u>patterns</u> in different regions of the world. Emphasize how climate patterns can be used to predict typical weather conditions.

■ **Standard 3.1.3** **Design a solution** that reduces the <u>effects</u> of a weather-related hazard. *Generate and compare multiple possible solutions to a problem, plan and carry out fair tests to identify aspects of the model or prototype that can be improved, and evaluate the solutions based on how well each meets the criteria and constraints of the problem.* Examples could include barriers to prevent flooding or wind-resistant roofs.

Strand 3.2: EFFECTS OF TRAITS ON SURVIVAL

Plants and animals have unique and diverse life cycles, but they all follow a pattern of birth, growth, reproduction, and death. Different organisms vary in how they look and function because they have different inherited information. An organism's traits are inherited from its parents and can be influenced by the environment. Variations in traits between individuals in a population may provide advantages in surviving and reproducing in particular environments. When the environment changes some organisms have traits that allow them to survive, some move to new locations, and some do not survive.

- **Standard 3.2.1** **Develop models** to describe <u>patterns</u> of change that organisms go through during their life cycles. Emphasize that organisms have unique and diverse life cycles, but all have in common birth, growth, reproduction, and death.

- **Standard 3.2.2** **Analyze data** and identify <u>patterns</u> to provide evidence that plants and animals have traits inherited from parents. Examples of patterns could include the similarities and differences in traits between parent organisms and offspring and variation of traits in groups of similar organisms. Emphasize plants and non-human animals.

- **Standard 3.2.3** **Construct an explanation** supported by evidence that the environment can <u>affect</u> the traits of an organism. Examples could include normally tall plants grown with insufficient water are stunted and pets that are given too much food and little exercise may become overweight.

- **Standard 3.2.4** **Construct an explanation** supported by evidence for how variations in traits and behaviors can <u>affect</u> the ability of an individual to survive and reproduce. Examples of traits could include a plant with large thorns or strong smelling flowers and an animal's camouflage, thick fur, or ear length. Examples of behaviors could include animals living in groups, shivering or using the sun for warmth, or migrating with changes of the season.

- **Standard 3.2.5** **Engage in argument** from evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all. Emphasize that organisms have adaptations that <u>affect</u> how well they survive in a specific environment.

- **Standard 3.2.6** **Design a solution** to a problem caused by a change in the environment that <u>affects</u> the types of plants and animals living there. *Generate and compare multiple possible solutions to a problem and evaluate the solutions based on how well each meets the criteria and constraints of the problem.* Examples of environmental changes could include changes in land use, water availability, temperature, food, and changes caused by other organisms.

Strand 3.3: FORCE AFFECTS MOTION

Forces act on objects and have both a strength and a direction. An object at rest typically has multiple forces acting on it, but they are balanced, resulting in a zero net force on the object. Forces that are unbalanced, can cause changes in an object's speed or direction of motion. The patterns of an object's motion in various situations can be observed, measured, and used to predict future motion. Forces are exerted when objects come in contact with each other, however some forces can act on objects that are not in contact. The gravitational force of Earth, acting on an object near Earth's surface pulls that object toward the planet's center. Electric and magnetic forces between a pair of objects can act at a distance. The strength of these non-contact forces depends on the properties of the objects and the distance between the objects.

- **Standard 3.3.1** **Plan and carry out investigations** that provide evidence of the <u>effects</u> of balanced and unbalanced forces on the motion of an object. Examples could include an unbalanced force on one side of a ball causing it to move and balanced forces pushing on a box from both sides producing no movement. Emphasize using fair tests by changing only one variable at a time.

- **Standard 3.3.2** **Analyze data** from observations and measurements of an object's motion to identify <u>patterns</u> that can be used to predict future motion. Examples of motion with a predictable pattern could include a child swinging in a swing, a ball rolling back and forth in a bowl, and two children on a see-saw.

- **Standard 3.3.3** **Construct an explanation** supported by evidence that the gravitational force exerted by Earth <u>causes</u> objects to be directed down, toward the center of the spherical Earth. Emphasize that "down" is a local description depending on one's position on Earth.

- **Standard 3.3.4** **Plan and carry out an investigation** to determine <u>cause and effect</u> relationships of electric or magnetic interactions between two objects not in contact with each other. Examples could include the force on hair from an electrically charged balloon, how magnet orientation affects the direction of a force, and how distance between objects affects the strength of a force.

- **Standard 3.3.5** **Define a problem** that can be solved by applying scientific ideas about magnets. *Identify the criteria for success and constraints on materials, time, or cost. Generate and compare multiple possible solutions to the problem.* Examples could include a latch that <u>functions</u> to keep a door shut and a <u>structure</u> that prevents two moving objects from touching each other.

INTRODUCTION | GRADE 4

Science Literacy for All Students

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Three Dimensions of Science[1]

Science education includes three dimensions of science understanding: science and engineering practices, crosscutting concepts, and disciplinary core ideas. Every standard includes each of the three dimensions; **Science and Engineering Practices are bolded**, <u>Crosscutting Concepts are underlined</u>, and Disciplinary Core Ideas are in normal font. Standards with *specific engineering expectations are italicized*.

Science and Engineering Practices	<u>Crosscutting Concepts</u>	Disciplinary Core Ideas
➧ Asking questions or defining problems ➧ Developing and using models ➧ Planning and carrying out investigations ➧ Analyzing and interpreting data ➧ Using mathematics and computational thinking ➧ Constructing explanations and designing solutions ➧ Engaging in argument from Evidence ➧ Obtaining, evaluating, and communicating information	➧ Patterns ➧ Cause and effect: mechanism and explanation ➧ Scale, proportion, and Quantity ➧ Systems and system models ➧ Energy and matter: flows, cycles, and conservation ➧ Structure and function ➧ Stability and change	➧ Earth and Space Science ➧ Life Science ➧ Physical Science ➧ Engineering

[1] NRC Framework K–12 Science Education: http://www.nap.edu/catalog.php?record_id=13165

Organization of Standards

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Grade Four |
Utah Science with Engineering Education (SEEd) Standards

The fourth grade SEEd standards support students use of patterns to understand phenomena in life, earth, and physical sciences. Students will gather information to explore patterns of structure and function in organisms and how these organisms sense and respond to their environment. Through studying fossils, students will compare past and present organisms to make inferences about organisms that lived long ago and the nature of their environments. Students will continue to use patterns to develop an understanding of the relationship between energy and motion. They will explore how energy can be transferred from place to place by moving objects or through heat, sound, light, and electrical currents. Students will develop and use models to learn how some forms of energy travel in waves and apply their understanding of wave patterns to design a way to transmit information. As students observe patterns in the sky, they will investigate why the Sun appears brighter than other stars and Earth's movement in space. By using patterns students will develop their understanding of life on Earth, energy transfer, and Earth's motion in space.

Strand 4.1: ORGANISMS FUNCTIONING IN THEIR ENVIRONMENT

Through the study of organisms, inferences can be made about environments both past and present. Plants and animals have both internal and external structures that serve various functions for growth, survival, behavior, and reproduction. Animals use different sense receptors specialized for particular kinds of information to understand and respond to their environment. Some kinds of plants and animals that once lived on Earth can no longer be found. However, fossils from these organisms provide evidence about the types of organisms that lived long ago and the nature of their environments. Additionally, the presence and location of certain fossil types indicate changes that have occurred in environments over time.

- **Standard 4.1.1** **Construct an explanation** from evidence that plants and animals have internal and external <u>structures</u> that <u>function</u> to support survival, growth, behavior, and reproduction. Emphasize comparing the internal and external structures of plants and animals within the same and across various Utah environments (deserts, wetlands, forests).

- **Standard 4.1.2** **Develop and use a model** of a <u>system</u> to describe that animals receive different types of information from their environment through their senses, process the information in their brain, and respond to the information. Examples could include how animals in Utah respond to different aspects of their environment such as sounds, temperature, and smell.

- **Standard 4.1.3** **Analyze and interpret data** from fossils to provide evidence of the <u>stability and change</u> in organisms and environments from long ago. Examples of fossils and environments could include comparing a trilobite with a horseshoe crab, using a fossil footprint to determine the size of a dinosaur, and comparing a fossilized leaf to a modern leaf. Emphasize using the external structures of fossils to make inferences about ancient organisms.

- **Standard 4.1.4** **Engage in Argument from evidence** based on <u>patterns</u> in rock layers and fossils found in those layers to support an explanation for how an environment has changed over time. Examples could include tropical plant fossils found in Arctic areas and rock layers with marine shell fossils found above rock layers with plant fossils.

Strand 4.2: ENERGY TRANSFER

Energy is present whenever there are moving objects, sound, light, or heat. The faster a given object is moving, the more energy it possesses. When objects collide energy can be transferred from one object to another causing the object's motion to change. Energy can also be transferred from place to place by electrical currents, heat, sound, or light. Scientists and engineers apply an understanding of energy transfer to predict outcomes and design solutions to address everyday problems.

- **Standard 4.2.1** **Construct an explanation** using evidence to describe the <u>cause and effect</u> relationship between the speed of an object and the energy of that object. Examples could include a vehicle with more energy moves faster and a ball that is kicked harder travels a greater distance. Emphasize qualitative descriptions of the relationship between speed and energy.

- **Standard 4.2.2** **Ask questions** and predict outcomes about the <u>changes</u> in energy that occur when objects collide. Examples could include changes in speed when one moving ball collides with another and transfer of energy when a toy car hits a wall. Emphasize that energy transfers when objects collide.

- **Standard 4.2.3** **Plan and carry out an investigation** to gather evidence from observations that <u>energy</u> can be transferred from place to place by sound, light, heat, and electrical currents. Examples could include sound causing objects to vibrate and electric currents being used to produce motion or light.

- **Standard 4.2.4** Apply scientific ideas to **design a solution** that converts <u>energy</u> from one form to another. *Define the problem, identify criteria and constraints, develop a prototype for iterative testing, analyze data from testing, and propose modifications for optimizing the solution.* Examples could include solar ovens that convert light energy to heat energy and alarm systems that convert motion energy into sound energy.

Strand 4.3: WAVE PATTERNS

Waves are regular patterns of motion that transfer energy and have properties such as amplitude and wavelength. Waves in water can be directly observed. Light and sound waves are difficult to observe, but can be explored using models. A model can be used to explain how objects can be seen or sounds can be heard. Humans use waves and other patterns to transfer information.

- **Standard 4.3.1** **Develop a model** to describe the regular patterns of waves and that waves can cause objects to move. Examples of models could include diagrams, analogies, and physical models (such as water or rope). Emphasize patterns in terms of amplitude and wavelength.

- **Standard 4.3.2** **Develop a model** to describe how visible light waves reflected from objects enter the eye causing objects to be seen. Emphasize the reflection and movement of light. Understanding why we see color and the mechanisms of vision will be discussed in later grades.

- **Standard 4.3.3** Patterns are used to transfer information. **Design a solution** that transfers information by encoding, sending, receiving, and decoding. *Define the problem, identify criteria and constraints, develop a prototype for iterative testing, analyze data from testing, and propose modifications for optimizing the solution.* Examples could include drums sending coded information through sound waves, using a grid of 1's and 0's representing black and white to send information about a picture, and using Morse code to send text.

Strand 4.4: OBSERVABLE PATTERNS IN THE SKY

The Sun is a star that appears larger and brighter than other stars because it is closer to Earth. Stars range greatly in their distance from Earth. The orbit of Earth around the Sun and the rotation of Earth on its axis cause observable patterns.

- **Standard 4.4.1** **Construct an explanation** that differences in the apparent brightness of the Sun compared to other stars is due to <u>scale</u>. Emphasize relative distance from Earth, not sizes of stars.

- **Standard 4.4.2** **Analyze and interpret data** of observable <u>patterns</u> to show that Earth rotates on its axis and revolves around the Sun. Examples of patterns could include day and night, daily changes in length and direction of shadows, and seasonal appearance of some stars in the night sky. Emphasize patterns that reveal Earth's revolution and rotation. Earth's seasons and the tilt of Earth's axis will be introduced in middle-school.

INTRODUCTION | GRADE 5

Science Literacy for All Students

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Three Dimensions of Science[1]

Science education includes three dimensions of science understanding: science and engineering practices, crosscutting concepts, and disciplinary core ideas. Every standard includes each of the three dimensions; **Science and Engineering Practices are bolded**, <u>Crosscutting Concepts are underlined</u>, and Disciplinary Core Ideas are in normal font. Standards with *specific engineering expectations are italicized*.

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Organization of Standards

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Grade Five |
Utah Science with Engineering Education (SEEd) Standards

The fifth grade SEEd standards provide a framework for student understanding of the cycling of matter through observable phenomena. Students will investigate the interactions of matter in and among Earth's systems by exploring Earth's geologic features, water resources, and the processes of weathering and erosion. Students will design solutions to minimize the impact of natural hazards occurring in Earth's systems. Students will also build an understanding that matter is made of particles that are too small to be seen. They will investigate patterns and properties of matter, explore the outcomes of mixing substances, and use mathematical reasoning to understand conservation of matter. Students will investigate the cycling of matter through food chains in ecosystems to expand their understanding of interactions among Earth's systems. By applying knowledge of Earth's systems, students will design solutions to protect Earth's resources and environments.

Strand 5.1: CHARACTERISTICS AND INTERACTIONS OF EARTH'S SYSTEMS

Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's land and water features. Weathering and erosion are examples of interactions between Earth systems. Some interactions cause landslides, earthquakes, and volcanic eruptions that impact humans and other living things. Humans cannot eliminate natural hazards, but solutions can be designed to reduce their impact.

- **Standard 5.1.1** **Analyze and interpret data** to describe patterns of Earth's features. Examples of data could include topographic maps showing locations of mountains on continents or the ocean floor and the locations of volcanoes or earthquakes.

- **Standard 5.1.2** **Use mathematics and computational thinking** to compare the quantity of salt water and fresh water in various reservoirs to provide evidence for the distribution of water on Earth. Emphasize oceans, lakes, rivers, glaciers, groundwater, and polar ice caps Examples of using mathematics and computational thinking could include measuring, estimating, graphing, and finding percentages of quantities.

- **Standard 5.1.3** **Develop a model** to describe interactions between Earth's systems including the geosphere, biosphere, hydrosphere, and/or atmosphere. Emphasize interactions between two systems at a time. Examples could include the interaction of water with ecosystems, landforms, or climate and the influence of landforms on weather or ecosystems.

- **Standard 5.1.4** **Plan and carry out investigations** to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. Emphasize making observations and collecting data. Examples could include changing the slope in the downhill movement of water and observing the cycles of freezing and thawing of water.

- **Standard 5.1.5** **Design solutions** to reduce the effects of naturally occurring events that impact humans. *Define the problem, identify criteria and constraints, develop a prototype for iterative testing, analyze data from testing, and propose modifications for optimizing the solution.* Examples of events could include landslides, earthquakes, tsunamis, blizzards, and volcanic eruptions.

Strand 5.2: PROPERTIES AND CHANGES OF MATTER

All substances are composed of matter. Matter is made up of particles that are too small to be seen, but even then it still exists and can be detected by other means. Matter has specific properties by which it can be identified. When two or more different substances are mixed, a new substance with different properties may be formed. Whether a change forms a new substance or not, the total amount of matter is always conserved.

- **Standard 5.2.1** **Develop and use a model** to describe that matter is made of particles on a <u>scale</u> that is too small to be seen. Emphasize a focus on particles in general. Examples could include gases taking up space and dissolving substances in water. The use of the terms atoms and molecules will be introduced in middle school.

- **Standard 5.2.2** **Plan and carry out investigations** to identify substances based on <u>patterns</u> of their properties. Examples of substances could include powders, metals, minerals, and liquids. Examples of properties could include color, hardness, conductivity, solubility, and response to magnetic forces.

- **Standard 5.2.3** **Plan and carry out an investigation** to determine whether the mixing of two or more substances results (<u>cause and effect</u>) in new substances. Examples of substances could be vinegar and baking soda or rusting an iron nail in water.

- **Standard 5.2.4** **Use mathematics and computational thinking** to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of <u>matter</u> is conserved. Examples could include phase changes, dissolving, and mixing that results in new substances.

Strand 5.3: CYCLING OF MATTER IN ECOSYSTEMS

Matter cycles within ecosystems and can be traced from organism to organism. Through the process of photosynthesis, plants use energy from the Sun to change air and water into matter needed for growth. Animals and decomposers consume the plant matter, continuing the cycling of matter in a food chain. Human behavior can impact the cycling of matter. Scientists and engineers design solutions to protect Earth's systems.

- **Standard 5.3.1** **Construct an explanation supported by evidence** that plants use air, water, and energy from sunlight to produce plant matter needed for growth. Emphasize photosynthesis at a conceptual level where plant matter comes mostly from air and water and not from the soil. Photosynthesis at the cellular level will be introduced in middle school.

- **Standard 5.3.2** **Develop and use a model** to describe the movement of matter among plants, animals, decomposers, and the environment. Emphasize that plants use energy from the Sun to change matter that is not food (air, water, decomposed materials in soil) into matter that is food. Simple food chains should be discussed; complex interactions in a food web will be introduced in middle school.

- **Standard 5.3.3** **Design a solution** whose primary function is to protect Earth's resources and environments. *Define the problem, identify criteria and constraints, develop a prototype for iterative testing, analyze data from testing, and purpose modifications for optimizing the design solution*. Examples could include ways that humans can balance everyday needs (agriculture, industry, and energy) with protecting Earth’s resources and environments.

INTRODUCTION | BIOLOGY

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Biology | Utah Science with Engineering Education (SEEd) Standards

The biology SEEd standards focus on patterns, processes, relationships, and the environment of living organisms. Students will explore the role of matter cycles and energy flow when organisms interact with their environment. Through these interactions, the stability and change of an ecosystem can be affected, resulting in changes to biodiversity. Students will investigate the structures and functions of living organisms. Living organisms have a hierarchy of structures, the basic unit being the cell, in order to support necessary life functions including growth, obtaining energy, maintaining homeostasis, and reproduction. Students will explore the cause and effect relationships of heredity (the passing of genetic information from parent to offspring). The role of DNA in gene expression and protein synthesis, along with an understanding of how gene expression can be altered by environmental and genetic causes, is fundamental to understanding how life works. Students will investigate how the mechanisms of genetic variation can lead to diversity within and among species. The unity among species as well as the great diversity of species is a result of evolution by natural selection.

Strand BIO.1: INTERACTIONS WITH ORGANISMS AND THE ENVIRONMENT

The cycling of matter and flow of energy are part of a complex system of interactions within an ecosystem. Through these interactions, an ecosystem can sustain relatively stable numbers and types of organisms. Organism's individual and group behaviors can affect their ability to survive and reproduce. A stable ecosystem is capable of recovering from moderate biological and physical changes. Extreme changes may have significant impact on an ecosystem's carrying capacity and biodiversity, causing a new ecosystem to form. Human activities can lead to significant impacts on an ecosystem, including extinction of species.

- **Standard BIO.1.1** **Plan and carry out an investigation** in order to **collect and analyze data** to determine how biotic and abiotic factors can affect the stability and change of a population's carrying capacity and an ecosystem's biodiversity.

- **Standard BIO.1.2** **Construct an explanation** for the role of cycling of matter and flow of energy among organisms in an ecosystem. Emphasize the movement of matter and energy through different trophic levels of an ecosystem. Examples could include food chains, food webs, energy pyramids or pyramids of biomass.

- **Standard BIO.1.3** **Collect and analyze data** to determine the role of photosynthesis and cellular respiration and the scale and proportion of carbon reservoirs in the carbon cycle. Emphasize the cycling of carbon through the biosphere, atmosphere, hydrosphere, geosphere and how changes to the scale and proportion of various reservoirs impacts ecosystems. Examples of changes to the scale and proportion of reservoirs could include deforestation, fossil fuel combustion, and ocean uptake of carbon dioxide.

- **Standard BIO.1.4** **Develop an argument from evidence** for how ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but how changing conditions during succession may result in a new ecosystem. Examples of changes in ecosystem conditions could include moderate biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.

- **Standard BIO.1.5** **Define a problem** and *design, evaluate, and refine a solution for reducing* the impact caused by human activities on the environment and biodiversity. Examples of human activities could include urbanization, building dams, pollution, deforestation and introduction of invasive species.

Strand BIO.2: STRUCTURE AND FUNCTION OF LIFE

All living things are made of one or more cells. Multicellular organisms have systems of tissues and organs that work together to meet the needs of the whole organism. Feedback systems help organisms maintain homeostasis. Cells grow, divide and function in order to accomplish essential life processes. The structure and function of a cell determines the cell's role in an organism. Living cells are composed of chemical elements and molecules that form macromolecules. The macromolecules in a cell function to carry out important reactions that allow cycling of matter and flow of energy within and between living things.

■ **Standard BIO.2.1** **Engage in argument from evidence** that multicellular organisms have a <u>pattern</u> of hierarchical structural organization, in which the basic unit of life is the cell, cells form tissues, tissues form organs, organs form systems, and multiple systems form organisms.

■ **Standard BIO.2.2** **Ask questions** about the <u>structure and function</u> of interacting organs and organ <u>systems</u> that make up multicellular organisms. Emphasize the following organ systems and component organs: circulatory (heart, veins, arteries, capillaries), excretory (kidneys, liver, skin), digestive (mouth, stomach, small intestine [villi], large intestine, pancreas), respiratory (lungs [alveoli], diaphragm), nervous (neurons, brain, spinal cord), muscular, and skeletal.

■ **Standard BIO.2.3** **Obtain, evaluate, and communicate** information that shows similarities and differences in <u>structure and function</u> of plant and animal organ systems. Emphasize the following plant organ systems: shoot system (stem, buds, leaves, flowers) and root system.

■ **Standard BIO.2.4** **Plan and carry out an investigation** to provide evidence of homeostasis and that feedback mechanisms maintain <u>stability</u> in organisms. Examples of investigations could include heart rate response to changes in activity, stomata response to changes in moisture or temperature, and root development in response to variations in water level.

■ **Standard BIO.2.5** **Construct an explanation** based on evidence that all living things are primarily composed of carbon, hydrogen, oxygen, and nitrogen, and that the <u>matter</u> taken into an organism is broken down and recombined to make macromolecules necessary for life functions. Emphasize that molecules are broken apart during digestion and cellular respiration and the atoms involved are used to make carbohydrates, proteins, fats and nucleic acids.

■ **Standard BIO.2.6** **Develop and use a model** to describe the role of protein molecules as essential to the structure and function of the cell and living systems. Emphasize the role of enzymes to facilitate chemical reactions in cells.

■ **Standard BIO.2.7** **Ask questions** to **investigate** the structure and function of cells and how the proportion and quantity of organelles and the shape of cells result in cells with specialized functions. Examples could include mitochondria in muscle and nerve cells, chloroplasts in the surface cells of leaves, ribosomes in pancreatic cells, and the shape of nerve cells and muscle cells.

■ **Standard BIO.2.8** **Develop and use a model** to illustrate the cycling of matter and flow of energy through livings things by the processes of photosynthesis and cellular respiration. Emphasize that the products of one reaction are the reactants for the other and that energy is transferred during these reactions.

■ **Standard BIO.2.9** **Plan and carry out an investigation** to demonstrate how cells maintain stability within a range of changing conditions by the transport of materials across the cell membrane. Emphasize osmosis, diffusion, active transport and passive transport.

■ **Standard BIO.2.10** **Construct an explanation** using evidence about the role of mitosis in the production, growth, and maintenance of systems within complex organisms. Emphasize the major events of the cell cycle, including cell growth and DNA replication, separation of chromosomes, and separation of cell contents.

Strand BIO.3: GENETIC PATTERNS

Heredity is a unifying biological principle that explains how Information is passed from parent to offspring through DNA (deoxyribonucleic acid) molecules in the form of chromosomes. Distinct sequences of DNA, genes, carry the code for specific proteins, which are responsible for the specific traits and life functions of organisms. There are predictable patterns of inheritance, however, changes in the DNA sequence and environmental factors may alter genetic expression. The variation and distribution of traits observed in a population depend on both genetic and environmental factors. Research in the field of heredity has led to the development of multiple genetic technologies that may improve the quality of life.

■ **Standard BIO.3.1** **Construct an explanation** for how the structure of DNA and RNA code for the structure of proteins, which regulate and carry out the essential functions of life, resulting in specific traits. Emphasize a conceptual understanding that the sequence of nucleotides in DNA determines the amino acid sequence of proteins through the processes of replication, transcription, and translation.

■ **Standard BIO.3.2** **Use computational thinking** to make predictions about how DNA in the form of genes carried on chromosomes is passed from parents to offspring through the processes of meiosis and fertilization during sexual reproduction. Emphasize the cause and effect relationship of genotype and phenotype. Examples could include pedigrees, karyotypes, genetic disorders, or Punnett squares to investigate different patterns of inheritance including dominance, codominance, incomplete dominance, sex-linked traits, and epigenetics.

■ **Standard BIO.3.3** **Engage in argument** based on evidence that inheritable genetic variations may be caused by new genetic combinations during meiosis and/or mutations caused either by viable errors occurring during meiotic replication or by environmental factors. Examples of genetic variations could include genetic recombination from crossing over and nondisjunction during meiosis; non-lethal errors occurring during replication by insertions, deletions, or substitutions; and/or heritable mutations caused by environmental factors like radiation, chemicals, and viruses.

■ **Standard BIO.3.4** **Plan and carry out an investigation and use mathematical thinking to interpret data** to explain the variation and patterns in distribution of the traits expressed in a population. Emphasize the distribution of traits as it relates to both genetic and environmental influences on the expression of traits. Examples of variation and patterns in distribution of traits could include sickle-cell anemia and malaria, the peppered moth and industrial emissions, hemoglobin levels in humans and high elevation, flowering time and climate, human skin color and UV light exposure, seasonal coat color, flower color and soil pH, or antibiotic resistance.

■ **Standard BIO.3.5** ***Define a problem*** *for which genetic engineering can provide a solution. Evaluate genetic engineering as a solution to this problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, as well as possible social, cultural, and environmental impacts or effects*. Examples of genetic engineering that could be investigated could include selective breeding, cloning, CRISPR, recombinant DNA, gene splicing, GMOs, transgenic organisms, genetic testing, and genealogical DNA tests.

Strand BIO.4: EVOLUTIONARY CHANGE

The unity among species, as evidenced in the fossil record, similarities in DNA and other biomolecules, anatomical structures, and embryonic development, is the result of evolution. Evolution also explains the diversity within and among species. Evolution by natural selection is the result of environmental factors selecting for and against genetic traits. Traits that allow an individual to survive and reproduce are likely to increase in the next generation, causing the proportions of specific traits to change within a population. Over longer periods of time, changes in proportions of traits due to natural selection, appearance of new traits due to mutation, and changes in selective pressures can cause both speciation and extinction. Human impacts on biodiversity in ecosystems affect the natural selection of species.

■ **Standard BIO.4.1** **Obtain, evaluate, and communicate** information to identify <u>patterns</u> that show that common ancestry and biological evolution are supported by multiple lines of evidence, such as similarities in DNA sequences, amino acid sequences, anatomical structures, the fossil record, and order of appearance of structures during embryological development.

■ **Standard BIO.4.2** **Construct an explanation based on evidence** that the process of evolution by natural selection is primarily <u>caused</u> by specific factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

■ **Standard BIO.4.3** **Analyze and interpret data** to identify <u>patterns</u> that support the claim that organisms with an advantageous heritable trait tend to increase in <u>proportion</u> to organisms lacking this trait.

■ **Standard BIO.4.4** **Obtain, evaluate and communicate information** about the <u>effect</u> of group behavior on individual and species' chances to survive and reproduce. Emphasize: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.

■ **Standard BIO.4.5** **Use evidence to construct an argument** that supports the claim that changes in environmental conditions may <u>cause</u> (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

■ **Standard BIO.4.6** **Analyze data** from a model to **construct an argument** for which solution(s) can best solve the problem. Emphasize *using a simulation to model possible solutions to a real-world problem* caused by natural selection and adaptation of populations. Examples of real-world problems could include bacterial or viral resistance to drugs, plant resistance to herbicides, or the effect of changes in climate on food sources.

INTRODUCTION | CHEMISTRY

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Organization of Standards

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Chemistry |
Utah Science with Engineering Education (SEEd) Standards

The chemistry SEEd standards explore the foundational principles of chemistry and allow students to investigate the ways that chemistry impacts everyday life. The strands emphasize the relationships between atomic and molecular structures and the properties of materials that we observe macroscopically using our senses and scientific instruments, that matter is conserved in chemical reactions and nutrient cycles, the ability of humans to design and control chemical systems for the benefit of society, and the ways that energy interacts with matter. A key skill is the ability to translate between macroscopic observations, molecular-level representations, and the symbolic notation used in chemical equations. In addition, connections to earth science, biology, physics, and engineering are examined through a chemistry lens, highlighting the ways that chemistry facilitates understanding in these fields.

Strand CHEM.1: THE STRUCTURE AND PROPERTIES OF MATTER

Particles of matter can have electrical charges. The attraction and repulsion between charged particles governs interactions at the atomic and molecular level. Atoms have nuclei, which are made of neutrons and positively charged protons. Negatively charged electrons surround, and are attracted to, the positively charged nucleus. The periodic table orders elements horizontally by the number of protons in the atom's nucleus, which identifies the element. The attractive forces between electrons and nuclei determine the chemical properties of elements. Elements with similar chemical properties are placed in columns on the periodic table, because the properties repeat in a regular pattern, and this pattern reflects patterns of outer electron states. Electrical charges cause atoms to bond, forming molecules and compounds. Molecules are also attracted to other atoms and molecules because of electrical charges. The structure and interactions of matter at the macroscopic scale are determined by electrical forces within and between atoms and molecules.

■ **Standard CHEM.1.1 Obtain, evaluate, and communicate information** regarding the structure of the atom on the basis of experimental evidence. Emphasize the relationship between proton number and element identity, isotopes, and electron energy levels in atoms. Examples could include the gold foil experiment, cathode ray tube, or atomic spectrum data.

■ **Standard CHEM.1.2 Use** the periodic table as **a model** to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. Emphasize conceptual understanding of trends and patterns. Examples could include trends in ionization energy, atomic radius, and/or electronegativity. Examples of properties for main group elements could include general reactivity, bonding type, and ion formation.

■ **Standard CHEM.1.3 Analyze data** to predict the type of bonding (ionic, covalent/molecular, or metallic) most likely to occur between two elements using the patterns of reactivity on the periodic table. Emphasize the types and strengths of attractions between charged particles. Examples could include the attraction between electrons on one atom and the nucleus of another atom in a covalent bond, or between ions in an ionic compound.

■ **Standard CHEM.1.4 Use models** to represent chemical systems. Emphasize the molecular-level and symbolic representations commonly used in chemistry. Examples could include Lewis dot structures, chemical formulas, ball and stick models, and/or physical models.

■ **Standard CHEM.1.5 Plan and conduct an investigation** to compare the properties of substances at the bulk scale and relate them to molecular structures. Emphasize the strength of electrical forces between particles. Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of properties could include melting point and boiling point, vapor pressure, dissolving of a substance, and surface tension.

■ **Standard CHEM.1.6 Engage in argument supported from evidence** that the functions of macromolecules are related to their chemical structures. Emphasize the roles of attractive forces between molecules. Examples could include interactions between base pairs in nucleic acids and hydrophobic and hydrophilic interactions in lipids and proteins.

■ **Standard CHEM.1.7 Ask questions and communicate information** about how the molecular structures in designed materials cause desired properties. Emphasize the design of materials to control their properties through chemistry. Examples could include teflon, pharmaceuticals that target active sites, and synthetic fabrics.

Strand CHEM.2: STABILITY AND CHANGE IN CHEMICAL SYSTEMS

Conservation of matter is an important principle to consider when describing the cycling of matter and the use of resources. When substances are combined, they may interact with each other to form a solution. This process is a physical change in which no new molecules are made. The proportion of substances in a solution can be represented with concentration. In a chemical change, the atoms are rearranged by breaking and forming bonds to create different molecules, which have different properties. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

■ **Standard CHEM.2.1 Use mathematical representations** to analyze the distribution and proportion of particles in solution. Emphasize proportional reasoning rather than unit conversion. Examples could include molarity, mass percentage, and parts per million (ppm) to compare concentration in environmental, biological, or synthetic systems.

■ **Standard CHEM.2.2 Analyze data** about the outcomes of simple chemical reactions based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. Emphasize that elements behave in predictable ways related to their position on the periodic table. Examples could include reactions between main group elements, combustion reactions, and reactions between Arrhenius acids and bases.

■ **Standard CHEM.2.3 Plan and carry out an investigation** to observe the change in properties of substances in a chemical reaction, and relate the macroscopically observed properties to the molecular level and the symbolic notation used in chemistry. Emphasize that the visible macroscopic changes in chemical reactions are a result of changes on the molecular level. Examples could include changes in color, or the production of a solid or gas.

■ **Standard CHEM.2.4 Use mathematical representations** to support the observation that matter is conserved during a chemical reaction. Emphasize the mole relationship between mass and quantity of particles and the proportional relationships in chemical relations. Examples could include ratios of reactants and products in a chemical reaction, simple stoichiometric calculations, and limiting and excess reagents.

■ **Standard CHEM.2.5 Obtain, evaluate, and communicate information** about the cycling of atoms through natural systems. Emphasize the conservation of atoms. Examples could include the cycling of carbon in organic matter, atmosphere, and oceans; the cycling of oxygen through respiration and photosynthesis; or the cycling of nitrogen through the atmosphere, soil, plants, and animals.

■ **Standard CHEM.2.6 Define problems** related to the development, management, and utilization of mineral resources (matter), by *specifying qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants*. Emphasize the conservation of matter, and minerals as a limited resource. Examples of Utah mineral resources could include copper, gold, molybdenum, silver, coal, oil, and natural gas. Examples of constraints could include cost, safety, reliability, as well as possible social, cultural, and environmental impacts.

Strand CHEM.3: REACTION EFFECTS IN CHEMICAL SYSTEMS

Chemical processes can be understood in terms of the collisions of molecules and the rearrangements of atoms. The rate at which chemical processes occur can be modified. In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. Chemists can control and design chemical systems to create desirable results, although sometimes there are also unintended consequences.

- **Standard CHEM.3.1** **Construct an explanation** using experimental evidence for why changes in reaction conditions affect the rate of change of a reaction. Emphasize collision theory as an explanatory principle. Examples of reaction conditions could include temperature, concentration, particle size, or presence of a catalyst.

- **Standard CHEM.3.2** **Design a solution** that would refine the design of a chemical system by specifying a change in conditions to produce increased or decreased amounts of a product at equilibrium. Emphasize a qualitative understanding of Le Chatelier's Principle and connections between macroscopic and molecular level changes. Examples of design solutions could include adding or removing reactants or products, and changing pressure or temperature.

- **Standard CHEM.3.3** **Obtain, evaluate, and communicate information** regarding the effects of designed chemicals in a complex real-world system. Emphasize the role of chemistry in solving problems, while acknowledging unintended consequences. Examples could include ozone depletion and restoration, the Haber process, DDT, development of medicines, the preservation of historical artifacts, or bisphenol-A.

Strand CHEM.4: ENERGY IN CHEMICAL SYSTEMS

The energy of a system depends on the motion and interactions of matter and radiation within that system. When bonds are formed between atoms, energy is released. Energy must be provided when bonds are broken. A system's total energy is conserved as energy is continually transferred from one particle to another and between its various possible forms. When light or longer wavelength electromagnetic radiation is absorbed by matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of large amounts of energy. Society's demand for energy requires thinking creatively about ways to provide energy that don't deplete limited resources, or produce harmful emissions.

■ **Standard CHEM.4.1 Construct an argument from evidence** about whether a simple chemical reaction absorbs or releases <u>energy</u>, and relate the overall change in energy to the energy absorbed when bonds are broken and the energy released when bonds are formed. Emphasize conversion of energy from one form to another and conservation of total energy. Examples could include conversion of chemical potential energy to thermal energy in chemical or physical processes.

■ **Standard CHEM.4.2 Construct an explanation** of the <u>effects</u> that different frequencies of electromagnetic radiation have when absorbed by matter. Emphasize a qualitative understanding. Examples could include that low energy light increases bond vibration, visible light causes electronic transitions, and high energy light results in ionization and bond breaking.

■ **Standard CHEM.4.3** ***Design, build, and refine*** *a device that works within given constraints* to convert one form of <u>energy</u> into another form of energy. Emphasize chemical potential energy as a type of stored energy. Examples of devices could include batteries, chemical hot packs, or combustion of a fuel.

■ **Standard CHEM.4.4 Use models** to illustrate the changes in the composition of the nucleus of the atom, and compare the <u>energy</u> released during nuclear processes to the energy released during chemical processes. Emphasize a qualitative understanding of nuclear changes. Examples of nuclear processes could include the formation of elements through fusion in stars, generation of electricity in a nuclear power plant, radioactive decay, or the use of radioisotopes in nuclear medicine.

■ **Standard CHEM.4.5 Develop an argument from evidence** *to evaluate a proposed solution* to societal energy demands *based on prioritized criteria and trade-offs that account for a range of constraints that could include cost, safety, reliability, as well as possible social, cultural, and environmental impacts*. Examples could include nuclear, wind, solar, or geothermal power.

INTRODUCTION | EARTH AND SPACE SCIENCE

Science Literacy for All Students

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Earth and Space Science | Utah Science with Engineering Education (SEEd) Standards

Earth and space science (ESS) strands investigate processes and mechanisms that have resulted in the formation of our Earth, galaxy and universe. The ESS strands also examine Earth's interconnected systems that provide the habitable planet on which we reside, considering human impact on and future sustainability of these systems. Students will explore how technology has both driven exploration and discovery, and impacted our understanding of Earth's processes and systems on large and small scales. These systems have differing sources of energy, and matter cycles within and among them in multiple ways. Small changes in one part of one system can have large and sudden consequences in parts of other systems, or they can have no effect at all. These strands also emphasize Earth's structure and geologic processes, grounding investigations in phenomenal Utah geology and Utah's natural and energy resources. Understanding the relationships and interactions between Earth's systems provides understanding and mechanisms for natural phenomenon.

Strand ESS.1: MATTER AND ENERGY IN SPACE

The planet Earth is a tiny part of a vast universe that has developed over a huge expanse of time. The Big Bang theory addresses research and evidence regarding how the universe was formed. Models allow us to illustrate how elements found on Earth were at one time synthesized in stars, exemplifying the cycling of matter and flow of energy over immense scales. The structure of the solar system can be explained using multiple lines of evidence relating to its formation. Humans are innately curious and always pushing the bounds of discovery when it comes to the solar system, galaxy, and universe.

■ **Standard ESS.1.1** **Ask questions** and **obtain information** to compare the <u>size and scale</u> of objects within the solar system, the Milky Way galaxy, and the universe.

■ **Standard ESS.1.2** **Construct an argument based on evidence** as to how the Big Bang theory is based on astronomical evidence of electromagnetic <u>energy</u>, motion of distant galaxies measured with red-shift, and composition of <u>matter</u> in the universe. Emphasize the astronomical evidence of the redshift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).

■ **Standard ESS.1.3** **Develop a model** based on evidence to illustrate the <u>changes</u> occurring in the life spans of stars, element formation, and the role of nuclear fusion in a star's core to release energy as radiation. Emphasize the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.

■ **Standard ESS.1.4** **Construct an explanation** of the nebular theory of solar <u>system</u> formation and the evidence supporting it. Examples of evidence include: solar system structure due to gravity, motion, and temperature; composition and age of meteorites; and observations of newly forming stars.

■ **Standard ESS.1.5** **Evaluate and communicate** how space exploration and technology have <u>affected</u> our understanding of the universe. Emphasize technology and scientists' investigations of the universe. Examples could include land and space-based telescopes, space probes, human space missions, and satellites.

■ **Standard ESS.1.6** ***Design a solution*** *to a space exploration challenge by breaking it down into smaller, more manageable problems that can be solved using the* <u>*structure and function*</u> *of an engineered process or device.* Examples could include mitigation of space debris, radiation protection, food and water storage and preservation, advances in space rovers, or space probe design.

Strand ESS.2: EARTH'S STRUCTURE, PROCESSES, AND TECHNOLOGY

Earth's distinctive and layered internal structure can be explained through density differentiation relative to Earth's early history. The sources of Earth's internal heat are explainable. This heat promotes convection within the outer core and the mantle, driving the horizontal motion of Earth's lithospheric plates through mantle convection. A wide variety of observations and data gave rise to our current understanding of this motion and its wide-ranging implications. This comprehensive explanation of how our dynamic planet works is called the Theory of Plate Tectonics. Tectonic processes, acting over billions of years, have given rise to Utah's varied landscapes, resources, and hazards, which directly influence our state's economy and community well-being.

■ **Standard ESS.2.1** **Obtain and evaluate evidence** for the source of Earth's internal <u>heat</u> from radioactive decay and heat from the Earth's formation. **Develop and use a model** of this <u>system</u> to show how convection currents help distribute heat within the mantle.

■ **Standard ESS.2.2** **Analyze and interpret data** from seismic studies, composition of meteorites, and samples of the crust and mantle to **develop a model** of how cycling of Earth's <u>matter</u> and transfer of <u>energy</u> resulted in the internal structure of the Earth. Emphasis should be on identifying properties of chemical layers (crust, mantle, core) and physical layers (lithosphere, asthenosphere, mesosphere, inner and outer core).

■ **Standard ESS.2.3** **Engage in argument from evidence** to show how <u>patterns</u> between plate tectonics were discovered through technology to explain: (1) The location of volcanoes and the location and depth of earthquakes, (2) Continental and ocean floor features such as mountain ranges, mid-ocean ridges, oceanic trenches, faults, and fractures, (3) The distribution of rock types and fossils, (4) Age of rocks on the seafloor compared to the ages of rocks found on continents, (5) Magnetic polarity preserved in rocks on the seafloor. Examples of technology could include evidences from deep probes, seismic waves, ocean floor sonar, radiometric dating, and magnetic instruments.

■ **Standard ESS.2.4** **Use mathematical thinking to calculate** the <u>change</u> in the rate and direction of tectonic plate motion based on evidence from mantle plumes. Examples could include the movement and age of the Hawaiian Islands, and/or the movement and age of the Yellowstone Caldera.

■ **Standard ESS.2.5** **Construct an argument based on evidence** about the simultaneous co-evolution of Earth's systems and life on Earth, leading to periods of stability and change over geologic time. Examples could include volcanic eruptions causing mass extinctions, the evolution of Earth's atmosphere, or human settlement patterns and the availability of freshwater.

■ **Standard ESS.2.6** **Construct an explanation** for the formation of Utah's three geologic provinces based on patterns in the rock record (rock type and age) and types of geologic structures (types of faults, folds, and landforms). Emphasize: (1) Basin and Range: characterized by normal faulting (extensional), rocks of all types and ages, and north-south running narrow mountain ranges separated by wide, flat valleys. (2) Middle Rocky Mountains: characterized by thrust or reverse faults (compressional), folds, and rocks of all types ages and large, wide mountain ranges. (3) Colorado Plateau: characterized by minimal deformation (not much folding or faulting), rocks that are primarily sedimentary and Paleozoic in age and large flat plateaus with occasional laccolithic mountains.

■ **Standard ESS.2.7** **Ask questions** and ***evaluate possible solutions*** for the effects of hazards posed by natural disasters to human safety in the built environment. *Emphasize prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.* Examples of hazards posed by natural disasters could include earthquakes, landslides, floods, or wildfires.

Strand ESS.3: SYSTEMS WITHIN THE ATMOSPHERE AND HYDROSPHERE

Water's unique properties drive interactions among Earth's dynamic systems- the atmosphere, hydrosphere, geosphere and biosphere. As energy flows into and out of Earth's systems, changes occur. Systems and systems interactions can be described in terms of Earth's energy budget and models, including the cycling of carbon. Climate changes can occur if any of Earth's systems change (such as composition of the atmosphere, reflectivity of Earth's surface) through natural and human activity. Positive feedback loops can amplify the impacts of these effects, while negative feedback loops tend to maintain stable climate conditions. Current changes in climate can be compared to global climate records to help us understand how to maintain Earth's energy balance and life on Earth.

- **Standard ESS.3.1** **Plan and conduct an investigation** of the properties of water and its effects on Earth materials and surface processes. Investigations could include chemical and mechanical investigations into the relationship between water and the rock cycle, or water's role in weather, erosion, and deposition. Properties include water's capacity to absorb, store, and release energy; transmit sunlight; expand upon freezing; dissolve and transport materials, and lower the viscosities and melting points of rocks.

- **Standard ESS.3.2** **Construct an explanation** for how energy from the sun drives atmospheric processes and how atmospheric currents transport matter and transfer energy. Emphasize: (1) How energy from the sun is reflected, absorbed, or scattered, (2) How greenhouse effect contributes to atmospheric energy, (3) How uneven heating of Earth's atmosphere at the equator causes variations in the intensity and duration of sunlight striking Earth, (4) How uneven heating of Earth's atmosphere at the equator and polar regions combined with the Coriolis effect create an atmospheric circulation system that moves heat energy around the Earth.

- **Standard ESS.3.3** **Develop and use a model** to describe how changes in the Earth's energy budget affect Earth's climate over varying timescales. These changes include variations in the amount of incoming solar radiation due to Earth's orbit and tilt, solar output, albedo, and atmospheric composition. Include comparisons of the rate of change in the past with the rate of change today.

■ **Standard ESS.3.4** **Develop a quantitative model** to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. Emphasize how the movement of carbon from one system to another can result in changes to the system(s). Examples could include more carbon absorbed in the oceans leading to ocean acidification or more carbon present in the atmosphere leading to a stronger greenhouse effect.

■ **Standard ESS.3.5** **Analyze and interpret data** from global climate records to illustrate changing environments throughout geologic time, and make predictions about future variations in Earth's systems using modern trends. Examples of data could include: sea surface temperature, air temperature, borehole temperature, composition of gasses in ice cores, sediment core composition, tree rings, coral reefs.

■ **Standard ESS.3.6** **Analyze geoscience data** to make the claim that one change to Earth's surface can create feedback loops that cause changes to other Earth systems. Examples could include warming soils releasing methane leading to more warmer global temperatures, melting ice caps reduces albedo leading to ice melt, deforestation leading to increased erosion and/or energy use, or more pollutants in the atmosphere leading to increased air pollution.

Strand ESS.4: STABILITY AND CHANGE IN NATURAL RESOURCES

Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources, including air, water, minerals, metals, and energy. Some of these resources are renewable over human lifetimes, and some are nonrenewable. In Utah, discovery, development and extraction of natural and energy resources are driven by multiple factors, including social, economic and environmental. Often, competing views and priorities conflict in development or usage of resources, driving solutions for more efficient and clean processes. Resource management and allocation requires utilization of cost-benefit ratios and consideration of environmental, social and economic impacts.

■ **Standard ESS.4.1** **Construct an explanation** based on the evidence for how the availability of natural resources, the occurrence of natural hazards, and <u>changes</u> in climate have influenced human activity. Examples of natural resources could include air, water, precious metals, or fossil fuels. Examples of natural hazards could include earthquakes, fires, floods, and landslides.

■ **Standards ESS.4.2** **Obtain, evaluate, and communicate information** about how Utah's resource extraction and energy production/techniques <u>affects</u> social, environmental, and economic factors. Examples of resource extraction could include salt, copper, uranium, or potash. Examples of energy production could include conventional (coal, oil, natural gas), unconventional (oil shales and oil sands), and renewable resources (solar, wind, geothermal, hydroelectric and biomass). Examples of social, environmental, and economic factors could include industry, air or water quality and quantity, tourism/recreation, natural hazards, vegetation, and agriculture.

■ **Standard ESS.4.3** ***Evaluate*** *competing design solutions for developing, managing, and utilizing <u>energy</u> and mineral resources based on cost-benefit ratios*. Emphasis is on conservation, recycling, and reuse of resources (such as minerals and metals) where possible and on minimizing impact where it is not. Examples could include developing best practices for conventional (coal, oil, natural gas), unconventional (oil shales and oil sands), and renewable (solar, wind, geothermal, hydroelectric and biomass) energy resources.

■ **Standard ESS.4.4** **Analyze** *a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for the <u>effect</u> of societal needs and wants.* Emphasize that challenges could be at a global or local community level. Examples could include clean water, clean air, or energy sources that minimize pollution.

INTRODUCTION | PHYSICS

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Physics | Utah Science with Engineering Education (SEEd) Standards

Physics is the study of matter and energy at all scales throughout the universe. While matter is the "stuff" of the universe at all scales, energy is a quantity associated with any matter that helps us describe what it is doing or what it could potentially do. Material objects interact with one another and exchange energy through forces. These forces are relayed across space by fields, and a change of any field over time can produce waves that can both transfer energy and communicate information. Throughout all processes, matter and energy, collectively, are conserved in the universe and within closed systems. These principles provide a basis for all scientific disciplines and help us understand even more complicated systems in nature and in our own engineering and technology. In order to construct explanations of matter and energy, as well as the fields and forces between, physics investigates, seeks patterns, and develops models regarding the cause and effect relationships between all matter. These overarching themes are emphasized in SEEd standards in order to help students see the foundations of physics, organized into strands that focus on forces, energy, fields, and waves, as well as the interconnectedness between these.

Strand PHYS.1: FORCES AND INTERACTIONS

Uniform motion of an object is natural, but changes in motion are caused by a nonzero sum of forces. Such a "net force" causes an acceleration, a change in momentum, that always influences pairs of objects responsible for the actions upon one another. The time over which these paired forces are exerted determine the effects of these forces. These principles are critical to how systems are designed, whether these are static or interactive bodies.

■ **Standard PHYS.1.1** **Analyze data** to determine the <u>cause and effect</u> relationship between the net force on an object and its change in motion, as summarized by Newton's 2nd Law of Motion. Emphasize one-dimensional motion and to macroscopic objects moving at non-relativistic speeds. Examples could include objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.

■ **Standard PHYS.1.2** **Use mathematical representations** to support the claim that the total momentum of a <u>system</u> is conserved when there is no net force acting on the system. Emphasize quantitative conservation of momentum in interactions and the qualitative meaning of this principle. Examples could include one-dimensional elastic and inelastic collisions between objects within the system.

■ **Standard PHYS.1.3** **Apply science and engineering ideas to design, evaluate, and refine** the <u>structure</u> of a device to improve its <u>function</u> by minimizing the force on a macroscopic object during a collision. Emphasize the concept that for a given change in momentum, force in the direction of the change in momentum is decreased by increasing the time interval of the collision. Examples could include use of padding or parachutes. This is limited to qualitative evaluations and/or algebraic manipulations.

■ **Standard PHYS.1.4** **Design a solution** to an interest-driven complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering and iterative testing. Emphasize problems that require application of Newton's 2nd Law of Motion or changing or conservation of momentum. Examples could include problems that have prioritized criteria and trade-offs that account for constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Strand PHYS.2: ENERGY

Energy is a quantity not defined in terms of what it is but instead by the changes it causes to matter through energy transformations and transfers. Energy is a quantifiable property that is conserved in isolated systems, as well as in the universe in general. Examining the world through an energy lens allows us to model and predict complex interactions of multiple objects within a system.

■ **Standard PHYS.2.1** **Create a computational model** to calculate transfer of energy within a system. Emphasize identifying the components of the system, along with their initial and final energies, and algebraic description to depict energy transfer in the system. Examples could include using the computational model to predict the maximum possible change in the energy of one component of the system for a given set of energy flows, and identifying and describing the limitations of the computational model.

■ **Standard PHYS.2.2** **Develop and use models** to illustrate that energy at all levels can be accounted for as a combination of energies associated with the motion of objects and energy associated with the relative positions of objects. Emphasize relationships between components of the model to show that energy in all forms is conserved. Examples could include macroscopic phenomena as well as those occurring at molecular or atomic scales, such as changes in temperature, phase, or electron energy.

■ **Standard PHYS 2.3** **Design a device** that converts one form of energy into another form of energy and solves a complex real-life problem. Emphasize the evaluation of the device based on its criteria and constraints. Examples could include transformations from electrical energy to mechanical energy, mechanical energy to electrical energy, etc.

■ **Standard PHYS 2.4** **Define a problem and propose a solution** for a major global challenge that specifies qualitative and quantitative criteria and constraints and that accounts for societal needs and wants. Emphasize problems that require the application of conservation of energy principles through energy transfers and transformations. Examples could include feasibility studies to examine possible use of renewable energy resources to perform functions currently performed by nonrenewable fuels.

Strand PHYS.3: FIELDS

Fields describe how forces act through space and how potential energy is stored in systems. These take on different forms (e.g., electric, magnetic, gravitational), but similarly provide a mechanism for how matter interacts. These fields are important at a wide variety of scales, ranging from the subatomic to the astronomic.

■ **Standard PHYS.3.1** **Use mathematical representations** of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electric fields between objects, determining the forces between these objects. Emphasize scale and proportion when comparing the two laws.

■ **Standard PHYS.3.2** **Plan and conduct an investigation** to provide evidence that an electric current causes a magnetic field and that a changing magnetic field causes an electric current. Emphasize the qualitative relationship between electricity and magnetism without necessarily conducting quantitative analysis. Examples could include how electric currents cause magnetic fields, or how electric charges or changing magnetic fields cause electric fields.

■ **Standard PHYS.3.3** **Analyze data** to compare and contrast the electric and gravitational forces between two charged objects and the energy between them (qualitatively) as they change relative position. Emphasize the effect on force and energy as objects move relative to each other. Examples can include models, simulations, or experimental data which illustrate gravitational and electric field lines between two charged objects.

■ **Standard PHYS.3.4** **Develop and use a model** to evaluate the effects on a field as characteristics of its source and surrounding space are varied. Emphasize how a field changes with distance from its source. Examples could include the electrostatic field resulting from point charges, dipole magnets, or loops of electric current.

Strands PHYS.4: WAVES

Waves transfer energy through matter or space through an oscillation of fields or matter. Because waves depend upon the properties of fields and the predictable transformation of energy, they can be used to interpret the nature of matter and its energy. Waves are utilized to transmit information both in analog and digital forms.

■ **Standard PHYS.4.1** **Analyze and interpret data** using mathematical representations to support a claim from patterns regarding the relationships among the frequency, wavelength, and speed of waves traveling in various media. Emphasize algebraic relationships and describing those relationships qualitatively. Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.

■ **Standard PHYS.4.2** **Evaluate questions** about the advantages and disadvantages of using digital transmission and storage of information and their impacts on society. Emphasis should include stability of digital signals and the discrete nature of change to transmit information. Examples of advantages could include that only digital information can be stored in computer memory, is transferred easily, and copied and shared rapidly; while disadvantages could include issues of easy deletion, fidelity based on sampling rates, security, and theft.

■ **Standard PHYS.4.3** **Evaluate the claims, evidence, and reasoning of an argument** that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. Emphasize how the experimental evidence supports the claim and how models and explanations are modified in light of new evidence. Examples could include resonance, interference, diffraction, and photoelectric effect.

■ **Standard PHYS.4.4** **Evaluate information** about the effects that different frequencies of electromagnetic radiation have when absorbed by biological materials. Emphasize that different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation.

■ **Standard PHYS.4.5** **Communicate** technical **information** about how devices use the principles of electromagnetic waves and their interactions with matter to transmit and capture information and energy. Examples could include reflection, refraction and absorption of light. Technical information could be used to develop system models of solar cells, medical imaging, or communications technology. This could include an evaluation of energy flows into and out of different systems.