UTAH CORE STANDARDS

June 2023

UTAH SCIENCE WITH ENGINEERING EDUCATION (SEEd) STANDARDS

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ADA compliant 12.01.2023

UTAH K–12
SCIENCE
WITH ENGINEERING EDUCATION (SEEd) STANDARDS

Adopted June 2023

by the
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January 2023

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Utah Science with Engineering Education Standards

Utah's Science and Engineering Education (SEEd) standards were written by Utah educators and scientists, using a wide array of resources and expertise. A great deal is known about good science instruction. The writing team used sources including *A Framework for K–12 Science Education*[1], the *Next Generation Science Standards*[2], and related works to craft research-based standards for Utah. These standards were written with students in mind, including developmentally appropriate progressions that foster learning that is simultaneously age-appropriate and enduring. The aim was to address what an educated citizenry should know and understand to embrace the value of scientific thinking and make informed decisions. The SEEd standards are founded on what science is, how science is learned, and the multiple dimensions of scientific work.

Principles of Scientific Literacy

Science is a way of knowing, a process for understanding the natural world. Engineering applies the fields of science, technology, and mathematics to produce solutions to real-world problems. The process of developing scientific knowledge includes ongoing questioning, testing, and refinement of ideas when supported by empirical evidence. Since progress in modern society is tied so closely to this way of knowing, scientific literacy is essential for a society to be engaged in political and economic choices on personal, local, regional, and global scales. As such, the Utah SEEd standards are based on the following essential elements of scientific literacy.

Science is valuable, relevant, and applicable.
Science produces knowledge that is inherently important to our society and culture. Science and engineering support innovation and enhance the lives of individuals and society. Science is supported from and benefited by an equitable and democratic culture. Science is for all people, at all levels of education, and from all backgrounds.

Science is a shared way of knowing and doing.
Science learning experiences should celebrate curiosity, wonder, skepticism, precision, and accuracy. Scientific habits of mind include questioning, communicating, reasoning, analyzing, collaborating, and thinking critically. These values are shared within and across scientific disciplines, and should be embraced by students, teachers, and society at large.

Science is principled and enduring.
Scientific knowledge is constructed from empirical evidence; therefore, it is both changeable and durable. Science is based on observations and inferences, an understanding of scientific laws and theories, use of scientific methods, creativity, and collaboration. The Utah SEEd standards are based on current scientific theories, which are powerful and broad explanations of a wide range of phenomena; they are not simply guesses nor are they unchangeable facts. Science is principled in that it is limited to observable evidence. Science is also enduring in that theories are only accepted when they are robustly supported by multiple lines of peer reviewed evidence. The history of science demonstrates

how scientific knowledge can change and progress, and it is rooted in the cultures from which it emerged. Scientists, engineers, and society, are responsible for developing scientific understandings with integrity, supporting claims with existing and new evidence, interpreting competing explanations of phenomena, changing models purposefully, and finding applications that are ethical.

Principles of Science Learning

Just as science is an active endeavor, students best learn science by engaging in it. This includes gathering information through observations, reasoning, and communicating with others. It is not enough for students to read about or watch science from a distance; learners must become active participants in forming their ideas and engaging in scientific practice. The Utah SEEd standards are based on several core philosophical and research-based underpinnings of science learning.

Science learning is personal and engaging.
Research in science education supports the assertion that students at all levels learn most when they are able to construct and reflect upon their ideas, both by themselves and in collaboration with others. Learning is not merely an act of retaining information but creating ideas informed by evidence and linked to previous ideas and experiences. Therefore, the most productive learning settings engage students in authentic experiences with natural phenomena or problems to be solved. Learners develop tools for understanding as they look for patterns, develop explanations, and communicate with others. Science education is most effective when learners invests in their own sense-making and their learning context provides an opportunity to engage with real-world problems.

Science learning is multi-purposed.
Science learning serves many purposes. We learn science because it brings us joy and appreciation but also because it solves problems, expands understanding, and informs society. It allows us to make predictions, improve our world, and mitigate challenges. An understanding of science and how it works is necessary in order to participate in a democratic society. So, not only is science a tool to be used by the future engineer or lab scientist but also by every citizen, every artist, and every other human who shares an appreciation for the world in which we live.

All students are capable of science learning.
Science learning is a right of all individuals and must be accessible to all students in equitable ways. Independent of grade level, geography, gender, economic status, cultural background, or any other demographic descriptor, all K–12 students are capable of science learning and science literacy. Science learning is most equitable when students have agency and can engage in practices of science and sense-making for themselves, under the guidance and mentoring of an effective teacher and within an environment that puts student experience at the center of instruction. Moreover, all students are capable learners of science, and all grades and classes should provide authentic, developmentally appropriate science instruction.

Three Dimensions of Science

Science is composed of multiple types of knowledge and tools. These include the processes of doing science, the structures that help us organize and connect our understandings, and the deep explanatory pieces of knowledge that provide predictive power. These facets of science are represented as "three dimensions" of science learning, and together these help us to make sense of all that science does and represents. These include science and engineering practices, crosscutting concepts, and disciplinary core ideas. Taken together, these represent how we use science to make sense of phenomena, and they are most meaningful when learned in concert with one another. These are described in *A Framework for K–12 Science Education*, referenced above, and briefly described here:

Science and Engineering Practices (SEPs): Practices refer to the things that scientists and engineers do and how they actively engage in their work. Scientists do much more than make hypotheses and test them with experiments. They engage in wonder, design, modeling, construction, communication, and collaboration. The practices describe the variety of activities that are necessary to do science, and they also imply how scientific thinking is related to thinking in other subjects, including math, writing, and the arts. For a further understanding of science and engineering practices see Chapter 3 in *A Framework for K–12 Science Education*.

Crosscutting Concepts (CCCs): Crosscutting concepts are the organizing structures that provide a framework for assembling pieces of scientific knowledge. They reach across disciplines and demonstrate how specific ideas are united into overarching principles. For example, a mechanical engineer might design some process that transfers energy from a fuel source into a moving part, while a biologist might study how predators and prey are interrelated. Both of these would need to model systems of energy to understand how all of the features interact, even though they are studying different subjects. Understanding crosscutting concepts enables us to make connections among different subjects and to utilize science in diverse settings. Additional information on crosscutting concepts can be found in Chapter 4 of *A Framework for K-12 Science Education*.

Disciplinary Core Ideas (DCIs): Core ideas within the SEEd Standards include those most fundamental and explanatory pieces of knowledge in a discipline. They are often what we traditionally associate with science knowledge and specific subject areas within science. These core ideas are organized within physical, life, and earth sciences, but within each area further specific organization is appropriate. All these core ideas are described in chapters 5 through 8 in the K–12 *Framework* text, and these are employed by the Utah SEEd standards to help clarify the focus of each strand in a grade level or content area.

Even though the science content covered by SEPs, CCCs, and DCIs is substantial, the Utah SEEd standards are not meant to address every scientific concept. Instead, these standards were written to address and engage in an appropriate depth of knowledge, including perspectives into how that knowledge is obtained and where it fits in broader contexts, for students to continue to use and expand their understandings over a lifetime.

Articulation of SEPs, CCCs, and DCIs

Science and Engineering Practices	Crosscutting Concepts	Disciplinary Core Ideas
Asking questions or defining problems: Students engage in asking testable questions and defining problems to pursue understandings of phenomena. **Developing and using models:** Students develop physical, conceptual, and other models to represent relationships, explain mechanisms, and predict outcomes. **Planning and carrying out investigations:** Students plan and conduct scientific investigations in order to test, revise, or develop explanations. **Analyzing and interpreting data:** Students analyze various types of data in order to create valid interpretations or to assess claims/conclusions. **Using mathematics and computational thinking:** Students use fundamental tools in science to compute relationships and interpret results. **Constructing explanations and designing solutions:** Students construct explanations about the world and design solutions to problems using observations that are consistent with current evidence and scientific principles. **Engaging in argument from evidence:** Students support their best explanations with lines of reasoning using evidence to defend their claims. **Obtaining, evaluating, and communicating information:** Students obtain, evaluate, and derive meaning from scientific information or presented evidence using appropriate scientific language. They communicate their findings clearly and persuasively in a variety of ways including written text, graphs, diagrams, charts, tables, or orally.	Patterns: Students observe patterns to organize and classify factors that influence relationships Cause and effect: Students investigate and explain causal relationships in order to make tests and predictions. Scale, proportion, and quantity: Students compare the scale, proportions, and quantities of measurements within and between various systems. Systems and system models: Students use models to explain the parameters and relationships that describe complex systems. Energy and matter: Students describe cycling of matter and flow of energy through systems, including transfer, transformation, and conservation of energy and matter. Structure and function: Students relate the shape and structure of an object or living thing to its properties and functions. Stability and change: Students evaluate how and why a natural or constructed system can change or remain stable over time.	Physical Sciences: (PS1) Matter and Its Interactions (PS2) Motion and Stability: Forces and Interactions (PS3) Energy (PS4) Waves Life Sciences: (LS1) Molecules to Organisms (LS2) Ecosystems (LS3) Heredity (LS4) Biological Evolution Earth and Space Sciences: (ESS1) Earth's Place in the Universe (ESS2) Earth's Systems (ESS3) Earth and Human Activity Engineering Design: (ETS1.A) Defining and Delimiting an Engineering Problem (ETS1.B) Developing Possible Solutions (ETS1.C) Optimizing the Design Solution **‣See the appendix for more information about the three dimensions.**

Organization of Standards

The Utah SEEd standards are organized into **strands** which represent significant areas of learning within grade level progressions and content areas. Each strand introduction is an orientation for the teacher in order to provide an overall view of the concepts needed for foundational understanding. These include descriptions of how the standards tie together thematically and which DCIs are used to unite that theme. Within each strand are **standards**. A standard is an articulation of how a learner may demonstrate their proficiency, incorporating not only the disciplinary core idea but also a crosscutting concept and a science and engineering practice. While a standard represents an essential element of what is expected, it does not dictate curriculum—it only represents a proficiency level for that grade. While some standards within a strand may be more comprehensive than others, all standards are essential for a comprehensive understanding of a strand's purpose.

The standards of any given grade or course are not independent. SEEd standards are written with developmental levels and learning progressions in mind so that many topics are built upon from one grade to another. In addition, SEPs and CCCs are especially well paralleled with other disciplines, including English language arts, fine arts, mathematics, and social sciences. Therefore, SEEd standards should be considered to exist not as an island unto themselves, but as a part of an integrated, comprehensive, and holistic educational experience.

Each standard is framed upon the three dimensions of science to represent a cohesive, multi-faceted science learning outcome.

- Within each SEEd Standard **Science and Engineering Practices are bolded**.
- Crosscutting Concepts are underlined.
- Disciplinary Core Ideas are added to the standard in normal font with the relevant DCIs codes from the *K–12 Framework* (indicated in parentheses after each standard) to provide further clarity.
- Standards with *specific engineering expectations are italicized*.
- Many standards contain additional emphasis and example statements that clarify the learning goals for students.
  - Emphasis statements highlight a required and necessary part of the student learning to satisfy that standard.
  - Example statements help to clarify the meaning of the standard and are not required for instruction.

An example of a SEEd standard:

- **Standard K.2.4** **Design and communicate a solution** to address the effects that living things (plants and animals, including humans) experience while trying to survive in their surroundings. *Define the problem by asking questions and gathering information, convey designs through sketches, drawings, or physical models, and compare designs*. Emphasize students working from a plant, animal, or human perspective. Examples could include a plant growing to get more sunlight, a beaver building a dam, or humans caring for the Earth by reusing and recycling natural resources. (ESS3.C, ETS1.A, ETS1.B, ETS1.C)

Each part of the above SEEd standard is identified in the following diagram:

Science and Engineering Practices (SEP) are bolded:

Design and communicate a solution to address the effects that living

Crosscutting Concepts (CCC) are underlined:

Design and communicate a solution to address the effects that living

Disciplinary Core Ideas (DCI) are added in the standard in regular/normal font:

Design and communicate a solution to address the effects that living things (plants and animals, including humans) experience while trying to survive in their surroundings. *Define the problem by asking questions*

Disciplinary Core Idea (DCI) codes are listed in parentheses at the end of each standard:

for the Earth by reusing and recycling natural resources. (ESS3.C, ETS1.A, ETS1.B, ETS1.C)

Engineering Expectations are italicized:

to survive in their surroundings. *Define the problem by asking questions and gathering information, convey designs through sketches, drawings, or physical models, and compare designs*. Emphasize students working from

Emphasis Statements start with the word "Emphasize…":

physical models, and compare designs. Emphasize students working from a plant, animal, or human perspective. Examples could include a plant

Example Statements start with "Examples could include…":

a plant, animal, or human perspective. Examples could include a plant growing to get more sunlight, a beaver building a dam, or humans caring for the Earth by reusing and recycling natural resources. (ESS3.C, ETS1.A,

Goal of the SEEd Standards

The Utah SEEd Standards is a research-grounded document aimed at providing accurate and appropriate guidance for educators and stakeholders. But above all else, the goal of this document is to provide students with the education they deserve, honoring their abilities, their potential, and their right to utilize scientific thought and skills for themselves and the world that they will build.

[1] National Research Council. 2012. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165. This consensus research document and its chapters are referred to throughout this document as a research basis for much of Utah's SEEd standards.

[2] Most Utah SEEd Standards are based on the Next Generation Science Standards (NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press) http://www.nextgenscience.org

KINDERGARTEN

INTRODUCTION

The kindergarten SEEd standards provide a framework for students to obtain, evaluate, and communicate information about how the Sun causes our weather patterns and how these patterns affect living systems. Students analyze information about the needs of living things (plants and animals, including humans) and how living things interact with their surroundings. Students investigate the effects of forces through push and pull interactions. Additionally, students design and evaluate solutions to problems that exist in these areas.

Strand K.1: WEATHER PATTERNS

Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather to identify patterns over time. Weather scientists forecast severe weather so that communities can prepare for and respond to these events. Sunlight warms Earth's surface.

- **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. Examples of data could include sunny, cloudy, windy, rainy, cold, or warm. (ESS2.D)

- **Standard K.1.2** **Obtain, evaluate, and communicate information** on the effect of forecasted weather patterns on human behavior. Examples could include how humans respond to local forecasts of typical and severe weather such as extreme heat, high winds, flash floods, thunderstorms, or snowstorms. (ESS3.B)

- **Standard K.1.3** **Carry out an investigation** using the five senses, to determine the effect of sunlight on different surfaces and materials. Examples could include measuring temperature, through touch or other methods, on natural and man-made materials in various locations throughout the day. (PS3.B)

- **Standard K.1.4** **Design a solution** that will reduce the warming effect of sunlight on an area. *Define the problem by asking questions and gathering information, convey designs through sketches, drawings, or physical models, and compare and test designs*. (PS3.B, ETS1.A, ETS1.B, ETS1.C)

Strand K.2: LIVING THINGS AND THEIR SURROUNDINGS

Living things (plants and animals, including humans) depend on their surroundings to get what they need, including food, water, shelter, and a favorable temperature. The characteristics of surroundings influence where living things are naturally found. Plants and animals affect and respond to their surroundings.

- **Standard K.2.1** **Obtain, evaluate, and communicate information** to describe patterns of what living things (plants and animals, including humans) need to survive. Emphasize the similarities and differences between the survival needs of all living things. Examples could include that plants depend on air, water, minerals, and light to survive, or animals depend on plants or other animals to survive. (LS1.C, LS2.B)

- **Standard K.2.2** **Obtain, evaluate, and communicate information** about patterns in the relationships between the needs of different living things (plants and animals, including humans) and the places they live. Emphasize that living things need water, air, and resources and that they live in places that have the things they need. Examples could include investigating plants grown in various locations and comparing the results or comparing animals with the places they live. (LS2.A ,LS2.B, ESS3.A)

- **Standard K.2.3** **Obtain, evaluate, and communicate information** about how living things (plants and animals, including humans) affect their surroundings to survive. Examples could include squirrels digging in the ground to hide their food, plant roots breaking concrete, or humans building shelters. (ESS2.E)

- **Standard K.2.4** **Design and communicate a solution** to address the effects that living things (plants and animals, including humans) experience while trying to survive in their surroundings. *Define the problem by asking questions and gathering information, convey designs through sketches, drawings, or physical models, and compare designs*. Emphasize students working from a plant, animal, or human perspective. Examples could include a plant growing to get more sunlight, a beaver building a dam, or humans caring for the Earth by reusing and recycling natural resources. (ESS3.C, ETS1.A, ETS1.B, ETS1.C)

Strand K.3: FORCES, MOTION, AND INTERACTIONS

The motion of objects can be observed and described. Pushing or pulling on an object can change the speed or direction of an object's motion and can start or stop it. Pushes and pulls can have different strengths and different directions. A bigger push or pull makes things go faster and when objects touch or collide, they push on one another and can change motion.

- **Standard K.3.1** **Plan and conduct an investigation** to compare the effects of different strengths or different directions of forces on the motion of an object. Emphasize forces as a push and pull on an object. The idea of strength should be kept separate from the idea of direction. Non-contact forces, such as magnets and static electricity, will be taught in Grades 3 through 5. (PS2.A, PS2.B, PS2.C, PS3.C)

- **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. *Define the problem by asking questions and gathering information, convey designs through sketches, drawings, or physical models, and compare and test designs*. 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. (PS2.A, PS2.B, PS2.C, PS3.C, ETS1.A, ETS1.B, ETS1.C)

GRADE 1

INTRODUCTION

The first-grade SEEd standards provide a framework for students to obtain, evaluate, and communicate information about seasonal and space patterns. Students investigate the needs of all living things including their offspring. Students model and investigate the effects of light and sound on objects or the effects of objects on light and sound. Additionally, students design and evaluate solutions to problems that exist in these areas.

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.

- **Standard 1.1.1** **Obtain, evaluate, and communicate information** about the movement of the Sun, Moon, and stars to describe predictable patterns. 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; or how stars, other than the Sun, are visible at night but not during the day. (ESS1.A)

- **Standard 1.1.2** **Obtain, evaluate, and communicate information** about the patterns observed at different times of the year 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. (ESS1.B)

- **Standard 1.1.3** **Design** a device that measures the varying patterns of daylight. *Define the problem by asking questions and gathering information, convey designs through sketches, drawings, or physical models, and compare and test designs*. Examples could include sundials for telling the time or tracking the movement of shadows throughout the day. (ESS1.B, ETS1.A, ETS1.B, ETS1.C)

Strand 1.2: THE NEEDS OF LIVING THINGS AND THEIR OFFSPRING

Living things (plants and animals, including humans) depend on their surroundings to get what they need, including food, water, shelter, and a favorable temperature. Plants and animals have external features that allow them to survive in a variety of environments. Young plants and animals 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 carry out an investigation** to determine the effect of sunlight and water on plant growth. Emphasize investigations that test one variable at a time. (LS1.C, LS2.A)
- **Standard 1.2.2** **Construct an explanation** by observing patterns of external features of living things that survive in different locations. Emphasize how plants and nonhuman animals, found in specific surroundings, share similar physical characteristics. Examples could include that plants living in dry areas are more likely to have thick outer coatings that hold in water, animals living in cold locations have longer and thicker fur, or most desert animals are awake at night. (LS1.A, LS1.D)
- **Standard 1.2.3** **Obtain, evaluate, and communicate information** about the patterns of plants and nonhuman animals that are alike, but not exactly like, their parents. An example could include that most carrots are orange and shaped like a cone but may be different sizes or have differing tastes. (LS3.A, LS3.B)
- **Standard 1.2.4** **Construct an explanation** of the patterns in the behaviors of parents and offspring which help offspring to survive. Examples of behavioral patterns could include the signals that offspring make such as crying, chirping, and other vocalizations or the responses of the parents such as feeding, comforting, and protecting the offspring. (LS1.B)

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 carry out 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. (PS4.A)

- **Standard 1.3.2** **Use a model** to show the effect of light on objects. Emphasize that objects can be seen when light is available to illuminate them or if they give off their own light. (PS4.B)

- **Standard 1.3.3** **Plan and carry out 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 clear plastic, wax paper, cardboard, or a mirror. (PS4.B)

- **Standard 1.3.4** **Design a device** in which the structure of the device uses light or sound to solve the problem of communicating over a distance. *Define the problem by asking questions and gathering information, convey designs through sketches, drawings, or physical models, and compare and test designs*. Examples of devices could include a light source to send signals, paper-cup-and-string telephones, or a pattern of drum beats. (PS4.C, ETS1.A, ETS1.B, ETS1.C)

GRADE 2

INTRODUCTION

The second-grade SEEd standards provide a framework for students to construct explanations for how matter on Earth's surface changes. Students investigate how living things live in habitats and have body structures that best fit their needs. Students use models to explain the forms and properties of matter. Additionally, students design solutions to problems that exist in these areas.

Strand 2.1: CHANGES IN THE EARTH'S SURFACE

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 and wind play a significant role in changing Earth's surface. The effects of wind and water can cause both slow and quick changes to the surface of the Earth. Scientists and engineers design solutions to slow or prevent wind or water from changing the land.

- **Standard 2.1.1** **Develop and use models** illustrating the patterns of landforms and water on Earth. Examples of models could include valleys, canyons, or floodplains and could depict water in the solid or liquid state. (ESS2.B, ESS2.C)
- **Standard 2.1.2** **Construct an explanation** about changes in Earth's surface that happen quickly or slowly. Emphasize the contrast between fast and slow changes. Examples of fast changes could include volcanic eruptions, earthquakes, or landslides. Examples of slow changes could include the erosion of mountains or the shaping of canyons. (ESS1.C)
- **Standard 2.1.3** **Design solutions** to slow or prevent wind or water from changing the shape of land. *Define the problem by asking questions and gathering information, convey designs through sketches, drawings, or physical models, and compare and test designs*. Examples of solutions could include retaining walls, dikes, windbreaks, shrubs, trees, and grass to hold back wind, water, and land. (ESS2.A, ETS1.A, ETS1.B, ETS1.C)

Strand 2.2: LIVING THINGS AND THEIR HABITATS

Living things (plants and animals, including humans) need water, air, and resources from the land to survive and live in habitats that provide these necessities. The physical characteristics of plants and animals reflect the habitat in which they live. 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 patterns of living things (plants and animals, including humans) in different habitats. Emphasize the diversity of living things in land and water habitats. Examples of patterns in habitats could include descriptions of temperature or precipitation and the types of plants and animals found in land habitats. (LS2.C, LS4.C, LS4.D)

- **Standard 2.2.2** **Plan and carry out an investigation** of the structure and function of plant and animal parts in different habitats. Emphasize how different plants and animals have different structures to survive in their habitat. Examples could include the shallow roots of a cactus in the desert or the seasonal changes in the fur coat of a wolf. (LS1.A, LS4.C, LS4.D)

- **Standard 2.2.3** **Develop and use a model** that mimics the function of an animal dispersing seeds or pollinating plants. Examples could include plants that have seeds with hooks or barbs that attach themselves to animal fur, feathers, or human clothing, or dispersal through the wind, or consumption of fruit and the disposal of the pits or seeds. (LS2.A)

- **Standard 2.2.4** **Design a solution** to a human problem by mimicking the structure and function of plants and/or animals and how they use their external parts to help them survive, grow, and meet their needs. *Define the problem by asking questions and gathering information, convey designs through sketches, drawings, or physical models, and compare and test designs*. Examples could include a human wearing a jacket to mimic the fur of an animal or a webbed foot to design a better swimming fin. (LS1.A, LS1.D, ETS1.A, ETS1.B, ETS1.C)

Strand 2.3: PROPERTIES OF MATTER

All things are made of matter which exists with different forms and properties. Matter can be described and classified by its observable properties. Materials with certain properties are well-suited for specific uses. Heating or cooling some types of matter may or may not irreversibly change their properties.

- **Standard 2.3.1** **Plan and carry out an investigation** to classify different kinds of materials based on patterns in their observable properties. Examples could include sorting materials based on similar properties such as strength, color, flexibility, hardness, texture, or whether the materials are solids or liquids. (PS1.A)

- **Standard 2.3.2** **Construct an explanation** showing how the properties of materials influence their intended use and function. Examples could include using wood as a building material because it is lightweight and strong or the use of concrete, steel, or cotton due to their unique properties. (PS1.A)

- **Standard 2.3.3** **Develop and use a model** to describe how an object, made of a small set of pieces, can be disassembled and reshaped into a new object with a different function. Emphasize that a great variety of objects can be built from a small set of pieces. Examples of pieces could include wooden blocks or building bricks. (PS1.A)

- **Standard 2.3.4** **Obtain, evaluate, and communicate information** about changes in matter caused by heating or cooling. Emphasize that some changes can be reversed and some cannot. Examples of reversible changes could include freezing water or melting crayons. Examples of irreversible changes could include cooking an egg or burning wood. (PS1.B)

GRADE 3

INTRODUCTION

The third-grade SEEd standards provide a framework for students to analyze and interpret data to reveal patterns that indicate typical weather conditions expected during a particular season. Students develop and use models to describe changes that organisms go through during their life cycle. Students plan and carry out investigations that provide evidence of the effects of balanced and unbalanced forces on the motion of an object. Additionally, students design solutions to problems that exist in these areas.

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 a range of an area's typical weather conditions and the extent to which those conditions vary over a long period of time. A variety of weather-related hazards result from natural processes. While humans cannot eliminate natural hazards, they can take steps to reduce their impact.

- **Standard 3.1.1** **Analyze and interpret data** to reveal patterns that indicate typical weather conditions expected during a particular season. Emphasize students gathering data in a variety of ways and representing data in tables and graphs. Examples of data could include temperature, precipitation, or wind speed. (ESS2.D)

- **Standard 3.1.2** **Obtain and communicate information** to describe climate patterns in different regions of the world. Emphasize how climate patterns can be used to predict typical weather conditions. Examples of climate patterns could be average seasonal temperature and average seasonal precipitation. (ESS2.D)

- **Standard 3.1.3** **Design a solution** that reduces the effects of a weather-related hazard. *Define the problem, identify criteria and constraints, develop possible solutions, analyze data from testing solutions, and propose modifications for optimizing a solution*. Examples could include barriers to prevent flooding or wind-resistant roofs. (ESS3.B, ETS1.A, ETS1.B, ETS1.C)

Strand 3.2: EFFECTS OF TRAITS ON SURVIVAL

Organisms (plants and animals, including humans) 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 traits. 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. Humans can design solutions to reduce the impact of environmental changes on organisms.

- **Standard 3.2.1** **Develop and use models** to describe changes that organisms go through during their life cycles. Emphasize that organisms have unique and diverse life cycles but follow a pattern of birth, growth, reproduction, and death. Examples of changes in life cycles could include how some plants and animals look different at different stages of life or how other plants and animals only appear to change size in their life. (LS1.B)

- **Standard 3.2.2** **Analyze and interpret data** to identify patterns of traits that plants and animals have inherited from parents. Emphasize the similarities and differences in traits between parent organisms and offspring and variation of traits in groups of similar organisms. (LS3.A, LS3.B)

- **Standard 3.2.3** **Construct an explanation** that the environment can affect the traits of an organism. Examples could include that the growth of normally tall plants is stunted with insufficient water or that pets given too much food and little exercise may become overweight. (LS3.B)

- **Standard 3.2.4** **Construct an explanation** showing how variations in traits and behaviors can affect the ability of an individual to survive and reproduce. Examples of traits could include large thorns protecting a plant from being eaten or strong smelling flowers to attracting certain pollinators. Examples of behaviors could include animals living in groups for protection or migrating to find more food. (LS2.D, LS4.B)

- **Standard 3.2.5** **Engage in argument from evidence** that in a particular habitat (system) some organisms can survive well, some survive less well, and some cannot survive at all. Emphasize that organisms and habitats form systems in which the parts depend upon each other. Examples of evidence could include needs and characteristics of the organisms and habitats involved such as cacti growing in dry, sandy soil but not surviving in wet, saturated soil. (LS4.C)

- **Standard 3.2.6** **Design a solution** to a problem caused by a change in the environment that impacts the types of plants and animals living in that environment. *Define the problem, identify criteria and constraints, and develop possible solutions*. Examples of environmental changes could include changes in land use, water availability, temperature, food, or changes caused by other organisms. (LS2.C, LS4.D, ETS1.A, ETS1.B, ETS1.C)

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 effects of balanced and unbalanced forces on the motion of an object. Emphasize investigations where only one variable is tested at a time. 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. (PS2.A, PS2.B)

- **Standard 3.3.2** **Analyze and interpret data** from observations and measurements of an object's motion to identify patterns in its motion that can be used to predict future motion. Examples of motion with a predictable pattern could include a child swinging on a swing or a ball rolling down a ramp. (PS2.A, PS2.C)

- **Standard 3.3.3** **Construct an explanation** that the gravitational force exerted by Earth causes objects to be directed downward, toward the center of the spherical Earth. Emphasize that "downward" is a local description depending on one's position on Earth. (PS2.B)

- **Standard 3.3.4** **Ask questions** to **plan and carry out an investigation** to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. Emphasize how static electricity and magnets can cause objects to move without touching. Examples could include the force an electrically charged balloon has on hair, how magnet orientation affects the direction of a force, or how distance between objects affects the strength of a force. Electrical charges and magnetic fields will be taught in Grades 6 through 8. (PS2.B)

- **Standard 3.3.5** **Design a solution** to a problem in which a device functions by using scientific ideas about magnets. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data from testing solutions, and propose modifications for optimizing a solution.* Examples could include a latch or lock used to keep a door shut or a device to keep two moving objects from touching each other. (PS2.B, ETS1.A, ETS1.B, ETS1.C)

GRADE 4

INTRODUCTION

The fourth-grade SEEd standards provide a framework for students to construct an explanation of how structures support growth, behavior, and survival in both plants and animals. Students analyze and interpret data from fossils to provide evidence of stability and change in ancient organisms and environments. Students plan and carry out an investigation to gather evidence that energy can be transferred from place to place by sound, light, heat, and electrical currents. Students analyze data and construct explanations for how the Sun and Earth interact. Additionally, students design solutions to problems that exist in these areas.

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 structures that function to support survival, growth, behavior, and reproduction. Emphasize how structures support an organism's survival in its environment and how internal and external structures of plants and animals vary within the same and across multiple Utah environments. Examples of structures could include thorns on a stem to prevent predation or gills on a fish to allow it to breathe underwater. (LS1.A)

- **Standard 4.1.2** **Develop and use a model** of a system to describe how animals receive different types of information from their environment through their senses, process the information in their brain, and respond to the information. Emphasize how animals are able to use their perceptions and memories to guide their actions. Examples could include models that explain how animals sense and then respond to different aspects of their environment such as sounds, temperature, or smell. (LS1.D)

- **Standard 4.1.3** **Analyze and interpret data** from fossils to provide evidence of the stability and change in organisms and environments from long ago. Emphasize using the structures of fossils to make inferences about ancient organisms. Examples of fossils and environments could include comparing a trilobite with a horseshoe crab in an ocean environment or using a fossil footprint to determine the size of a dinosaur. (LS4.A)

- **Standard 4.1.4** **Engage in argument from evidence** based on patterns in rock layers and fossils found in those layers to support an explanation that environments have changed over time. Emphasize the relationship between fossils and past environments. Examples could include tropical plant fossils found in Arctic areas and rock layers with marine shell fossils found above rock layers with land plant fossils. (ESS1.C)

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 objects' motions to change. Energy can also be transferred from place to place by electrical currents, heat, sound, or light. Devices can be designed to convert energy from one form to another.

- **Standard 4.2.1** **Construct an explanation** to describe the cause and effect relationship between the speed of an object and the energy of that object. Emphasize using qualitative descriptions of the relationship between speed and energy like fast, slow, strong, or weak. An example could include a ball that is kicked hard has more energy and travels a greater distance than a ball that is kicked softly. (PS3.A)
- **Standard 4.2.2** **Ask questions** and make observations about the changes in energy that occur when objects collide. Emphasize that energy is transferred when objects collide and may be converted to different forms of energy. Examples could include changes in speed when one moving ball collides with another or the transfer of energy when a toy car hits a wall. (PS3.B, PS3.C)
- **Standard 4.2.3** **Plan and carry out an investigation** to gather evidence from observations that energy 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. (PS3.A, PS3.B)
- **Standard 4.2.4** **Design** a device that converts energy from one form to another. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data from testing solutions, and propose modifications for optimizing a solution*. Emphasize identifying the initial and final forms of energy. Examples could include solar ovens that convert light energy to heat energy or a simple alarm system that converts motion energy into sound energy. (PS3.B, PS3.D, ETS1.A, ETS1.B, ETS1.C)

Strand 4.3: WAVE PATTERNS

Waves are regular patterns of motion that transfer energy and have properties such as amplitude (maximum distance of the wave crest from equilibrium) and wavelength (spacing between wave peaks). Waves in water can be directly observed. Light waves cause objects to be seen when light reflected from objects enters the eye. Humans use waves and other patterns to transfer information.

- **Standard 4.3.1** **Develop and use a model** to describe the regular patterns of waves. Emphasize patterns in terms of amplitude and wavelength. Examples of models could include diagrams, analogies, and physical models such as water or rope. (PS4.A)
- **Standard 4.3.2** **Develop and use 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. The structure and function of organs and organ systems and the relationship between color and wavelength will be taught in Grades 6 through 8. (PS4.B)
- **Standard 4.3.3** **Design a solution** to an information transfer problem using wave patterns. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data from testing solutions, and propose modifications for optimizing a solution*. Examples could include using light to transmit a message in Morse code or using lenses and mirrors to see objects that are far away. (PS4.C, ETS1.A, ETS1.B, ETS1.C)

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. The rotation of Earth on its axis and orbit of Earth around the Sun cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the Sun and stars at different times of the day, month, and year.

- **Standard 4.4.1** **Construct an explanation** that differences in the apparent brightness of the Sun compared to other stars is due to the relative distance (scale) of stars from Earth. Emphasize relative distance from Earth. (ESS1.A)

- **Standard 4.4.2** **Analyze and interpret data** of observable patterns to show that Earth rotates on its axis and revolves around the Sun. Emphasize patterns that provide evidence of Earth's rotation and orbits 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. Earth's seasons and its connection to the tilt of Earth's axis will be taught in Grades 6 through 8. (ESS1.B)

GRADE 5

INTRODUCTION

The fifth-grade SEEd standards provide a framework for students to analyze and interpret data about Earth's major systems and how they interact. Students plan and carry out investigations to explain the properties of matter and to determine if new substances form when matter is combined. Students construct explanations for how matter cycles and energy flows through environments and Earth's systems. Additionally, students design and evaluate solutions to problems that exist in these areas.

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). Within these systems, the location of Earth's land and water can be described. Also, these systems interact in multiple ways. Weathering and erosion are examples of interactions between Earth's systems. Some interactions cause landslides, earthquakes, and volcanic eruptions that impact humans and other organisms. 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. Emphasize most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans while major mountain chains may be found inside continents or near their edges. Examples of data could include maps showing locations of mountains on continents and the ocean floor or the locations of volcanoes and earthquakes. (ESS2.B)
- **Standard 5.1.2** **Use mathematics and computational thinking** to compare the quantity of saltwater and freshwater in various reservoirs to provide evidence for the distribution of water on Earth. Emphasize reservoirs such as oceans, lakes, rivers, glaciers, groundwater, and polar ice caps. Examples of using mathematics and computational thinking could include measuring, estimating, graphing, or finding percentages of quantities. (ESS2.C)
- **Standard 5.1.3** **Ask questions** to **plan and carry out investigations** that provide evidence for the effects of weathering and the rate of erosion on the geosphere. Emphasize weathering and erosion by water, ice, wind, gravity, or vegetation. Examples could include observing the effects of cycles of freezing and thawing of water on rock or changing the slope in the downhill movement of water. (ESS2.A, ESS2.E)
- **Standard 5.1.4** **Develop a model** to describe interactions between Earth's systems including the geosphere, biosphere, hydrosphere, and/or atmosphere. Emphasize interactions between only two systems at a time. Examples could include the influence of a rainstorm in a desert, waves on a shoreline, or mountains on clouds. (ESS2.A)
- **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 possible solutions using models, analyze data from testing solutions, and propose modifications for optimizing a solution*. Emphasize that humans cannot eliminate natural hazards, but they can take steps to reduce their impacts. Examples of events could include landslides, earthquakes, tsunamis, blizzards, or volcanic eruptions. (ESS3.B, ETS1.A, ETS1.B, ETS1.C)

Strand 5.2: PROPERTIES AND CHANGES OF MATTER

All substances are composed of matter. Matter is made of particles that are too small to be seen but still exist and can be detected by other means. Substances have specific properties by which they can be identified. When two or more different substances are combined a new substance with different properties may be formed. Whether a change results in 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 scale that is too small to be seen. Emphasize making observations of changes supported by a particle model of matter. Examples could include adding air to expand a balloon, compressing air in a syringe, adding food coloring to water, or dissolving salt in water and evaporating the water. The use of the terms atoms and molecules will be taught in Grades 6 through 8. (PS1.A)

- **Standard 5.2.2** **Ask questions** to **plan and carry out investigations** to identify substances based on patterns of their properties. Emphasize using properties to identify substances. Examples of properties could include color, hardness, conductivity, solubility, or a response to magnetic forces. Examples of substances could include powders, metals, minerals, or liquids. (PS1.A)

- **Standard 5.2.3** **Plan and carry out investigations** to determine the effect of combining two or more substances. Emphasize whether a new substance is or is not created by the formation of a new substance with different properties. Examples could include combining vinegar and baking soda or rusting an iron nail in water. (PS1.B)

- **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 combining substances, the total weight of matter is conserved. Examples could include melting an ice cube, dissolving salt in water, and combining baking soda and vinegar in a closed bag. (PS1.A, PS1.B)

Strand 5.3: CYCLING OF MATTER IN ECOSYSTEMS

Matter cycles within ecosystems and can be traced from organism to organism. Plants use energy from the Sun to change air and water into matter needed for growth. Animals and decomposers consume matter for their life functions, continuing the cycling of matter. Human behavior can affect the cycling of matter. Scientists and engineers design solutions to conserve Earth's environments and resources.

- **Standard 5.3.1** **Construct an explanation** that plants use air, water, and energy from sunlight to produce plant matter needed for growth. Emphasize photosynthesis at a conceptual level and that plant matter comes mostly from air and water, not from the soil. Photosynthesis at the cellular level will be taught in Grades 6 through 8. (LS1.C)
- **Standard 5.3.2** **Obtain, evaluate, and communicate information** that animals obtain energy and matter from the food they eat for body repair, growth, and motion and to maintain body warmth. Emphasize that the energy used by animals was once energy from the Sun. Cellular respiration will be taught in Grades 6 through 8. (PS3.D, LS1.C)
- **Standard 5.3.3** **Develop and use a model** to describe the movement of matter among plants, animals, decomposers, and the environment. Emphasize that matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Examples could include simple food chains from ecosystems such as deserts or oceans or diagrams of decomposers returning matter to the environment. Complex interactions in a food web will be taught in Grades 6 through 8. (LS2.A, LS2.B)
- **Standard 5.3.4** Evaluate **design solutions** whose primary function is to conserve Earth's environments and resources. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine an optimal solution*. Emphasize how humans can balance everyday needs (agriculture, industry, and energy) while conserving Earth's environments and resources. (ESS3.A, ESS3.C, ETS1.A, ETS1.B, ETS1.C)

GRADE 6

INTRODUCTION

The sixth-grade SEEd standards provide a framework for student understanding of the cycling of matter and the flow of energy through the study of observable phenomena on Earth. Students will explore the role of energy and gravity in the solar system as they compare the scale and properties of objects in the solar system and model the Sun-Earth-Moon system. These strands also emphasize heat energy as it affects some properties of matter, including states of matter and density. The relationship between heat energy and matter is observable in many phenomena on Earth, such as seasons, the water cycle, weather, and climates. Types of ecosystems on Earth are dependent upon the interaction of organisms with each other and with the physical environment. By researching interactions between the living and nonliving components of ecosystems, students will understand how the flow of energy and cycling of matter affects stability and change within their environment.

Strand 6.1: STRUCTURE AND MOTION WITHIN THE SOLAR SYSTEM

The solar system consists of the Sun, planets, and other objects within Sun's gravitational influence. Gravity is the force of attraction between masses. The Sun-Earth-Moon system provides an opportunity to study interactions between objects in the solar system that influence phenomena observed from Earth. Scientists use data from many sources to determine the scale and properties of objects in our solar system.

- **Standard 6.1.1** **Develop and use a model** of the Sun-Earth-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons. Examples of models could be physical, graphical, or conceptual. (ESS1.A, ESS1.B)
- **Standard 6.1.2** **Develop and use a model** to describe the role of gravity and inertia in orbital motions of objects in our solar system. (ESS1.B)
- **Standard 6.1.3** **Use computational thinking** to **analyze data** and determine the scale and properties of objects in the solar system. Examples of scale could include size or distance. Examples of properties could include layers, temperature, surface features, or orbital radius. Data sources could include Earth and space-based instruments such as telescopes or satellites. Types of data could include graphs, data tables, drawings, photographs, or models. (ESS1.A, ESS1.B)

Strand 6.2: ENERGY AFFECTS MATTER

Matter and energy are fundamental components of the universe. Matter is anything that has mass and takes up space. Transfer of energy creates change in matter. Changes between general states of matter can occur through the transfer of energy. Density describes how closely matter is packed together. Substances with a higher density have more matter in a given space than substances with a lower density. Changes in heat energy can alter the density of a material. Insulators resist the transfer of heat energy, while conductors easily transfer heat energy. These differences in energy flow can be used to design products to meet the needs of society.

- **Standard 6.2.1** **Develop models** to show that molecules are made of different kinds, proportions, and quantities of atoms. Emphasize understanding that there are differences between atoms and molecules, and that certain combinations of atoms form specific molecules. Examples of simple molecules could include water (H2O), atmospheric oxygen (O2), or carbon dioxide (CO2). (PS1.A)

- **Standard 6.2.2** **Develop a model** to predict the effect of heat energy on states of matter and density. Emphasize the arrangement of particles in states of matter (solid, liquid, or gas) and during phase changes (melting, freezing, condensing, and evaporating). (PS1.A, PS3.A)

- **Standard 6.2.3** **Plan and carry out an investigation** to determine the relationship between temperature, the amount of heat transferred, and the change of average particle motion in various types or amounts of matter. Emphasize recording and evaluating data, and communicating the results of the investigation. (PS3.A)

- **Standard 6.2.4** **Design** *an object, tool, or process* that minimizes or maximizes heat energy transfer. *Identify criteria and constraints, develop a prototype for iterative testing, analyze data from testing, and propose modifications for optimizing the* ***design solution***. Emphasize demonstrating how the structure of differing materials allows them to function as either conductors or insulators. (PS3.A, PS3.B, ETS1.A, ETS1.B, ETS1.C)

Strand 6.3: EARTH'S WEATHER PATTERNS AND CLIMATE

All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. Heat energy from the Sun, transmitted by radiation, is the primary source of energy that affects Earth's weather and drives the water cycle. Uneven heating across Earth's surface causes changes in density, which result in convection currents in water and air, creating patterns of atmospheric and oceanic circulation that determine regional and global climates.

- **Standard 6.3.1** **Develop a model** to describe how the cycling of water through Earth's systems is driven by energy from the Sun, gravitational forces, and density. (ESS2.C)

- **Standard 6.3.2** **Investigate** the interactions between air masses that cause changes in weather conditions. Collect and analyze weather data to provide evidence for how air masses flow from regions of high pressure to low pressure causing a change in weather. Examples of data collection could include field observations, laboratory experiments, weather maps, or diagrams. (ESS2.C, ESS2.D)

- **Standard 6.3.3** **Develop and use a model** to show how unequal heating of the Earth's systems causes patterns of atmospheric and oceanic circulation that determine regional climates. Emphasize how warm water and air move from the equator toward the poles. Examples of models could include Utah regional weather patterns such as lake-effect snow or wintertime temperature inversions. (ESS2.C, ESS2.D)

- **Standard 6.3.4** **Construct an explanation** supported by evidence for the role of the natural greenhouse effect in Earth's energy balance, and how it enables life to exist on Earth. Examples could include comparisons between Earth and other planets such as Venus or Mars. (ESS2.D)

Strand 6.4: STABILITY AND CHANGE IN ECOSYSTEMS

The study of ecosystems includes the interaction of organisms with each other and with the physical environment. Consistent interactions occur within and between species in various ecosystems as organisms obtain resources, change the environment, and are affected by the environment. This influences the flow of energy through an ecosystem, resulting in system variations. Additionally, ecosystems benefit humans through processes and resources, such as the production of food, water and air purification, and recreation opportunities. Scientists and engineers investigate interactions among organisms and evaluate design solutions to preserve biodiversity and ecosystem resources.

- **Standard 6.4.1** **Analyze data** to provide evidence for the effects of resource availability on organisms and populations in an ecosystem. **Ask questions** to predict how changes in resource availability affects organisms in those ecosystems. Examples could include water, food, or living space in Utah environments. (LS2.A)
- **Standard 6.4.2** **Construct an explanation** that predicts patterns of interactions among organisms across multiple ecosystems. Emphasize consistent interactions in different environments such as competition, predation, and mutualism. (LS2.A)
- **Standard 6.4.3** **Develop a model** to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. Emphasize food webs and the role of producers, consumers, and decomposers in various ecosystems. Examples could include Utah ecosystems such as mountains, Great Salt Lake, wetlands, or deserts. (LS2.B)
- **Standard 6.4.4** **Construct an argument supported by evidence** that the stability of populations is affected by changes to an ecosystem. Emphasize how changes to living and nonliving components in an ecosystem affect populations in that ecosystem. Examples could include Utah ecosystems such as mountains, Great Salt Lake, wetlands, or deserts. (LS2.C)
- **Standard 6.4.5** *Evaluate competing design solutions* for preserving ecosystem services that protect resources and biodiversity based on how well the solutions maintain stability within the ecosystem. Emphasize **obtaining, evaluating, and communicating information** of differing design solutions. Examples could include policies affecting ecosystems, responding to invasive species, or solutions for the preservation of ecosystem resources specific to Utah, such as air and water quality and prevention of soil erosion. (LS2.C, LS4.D, ETS1.A, ETS1.B, ETS1.C)

GRADE 7

INTRODUCTION

The seventh-grade SEEd standards look for relationships of cause and effect which enable students to pinpoint mechanisms of nature and allow them to make predictions. Students will explore how forces can cause changes in motion and are responsible for the transfer of energy and the cycling of matter. This takes place within and between a wide variety of systems from simple, short-term forces on individual objects to the deep, long-term forces that shape our planet. In turn, Earth's environments provide the conditions for life as we know it. Organisms survive and reproduce only to the extent that their own mechanisms and adaptations allow. Evidence for the evolutionary histories of life on Earth is provided through the fossil record, similarities in the various structures among species, organism development, and genetic similarities across all organisms. Additionally, mechanisms shaping Earth are understood as forces affecting the cycling of Earth's materials. Questions about cause and effect and the ongoing search for evidence in science, or science's ongoing search for evidence, drive this storyline.

Strand 7.1: FORCES ARE INTERACTIONS BETWEEN MATTER

Forces are push or pull interactions between two objects. Changes in motion, balance and stability, and transfers of energy are all facilitated by forces on matter. Forces, including electric, magnetic, and gravitational forces, can act on objects that are not in contact with each other. Scientists use data from many sources to examine the cause and effect relationships determined by different forces.

- **Standard 7.1.1** **Carry out an investigation** which provides evidence that a change in an object's motion is dependent on the mass of the object and the sum of the forces acting on it. *Various experimental designs should be evaluated to determine how well the investigation measures an object's motion*. Emphasize conceptual understanding of Newton's First and Second Laws. Calculations will only focus on one-dimensional movement; the use of vectors will be introduced in high school. (PS2.A, PS2.C, ETS1.A, ETS1.B, ETS1.C)

- **Standard 7.1.2** Apply Newton's Third Law to ***design a solution*** *to a problem involving the motion of two colliding objects in a system*. Examples could include collisions between two moving objects or between a moving object and a stationary object. (PS2.A, ETS1.A, ETS1.B, ETS1.C)

- **Standard 7.1.3** **Construct a model** using observational evidence to describe the nature of fields existing between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically charged objects) and the forces they exert. (PS2.B)

- **Standard 7.1.4** **Collect and analyze data** to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor. (PS2.B)

- **Standard 7.1.5** **Engage in argument from evidence** to support the claim that gravitational interactions within a system are attractive and dependent upon the masses of interacting objects. Examples of evidence for arguments could include mathematical data generated from various simulations. (PS2.B)

Strand 7.2: CHANGES TO EARTH OVER TIME

Earth's processes are dynamic and interactive and are the result of energy flowing and matter cycling within and among Earth's systems. Energy from the sun and Earth's internal heat are the main sources driving these processes. Plate tectonics is a unifying theory that explains crustal movements of Earth's surface, how and where different rocks form, the occurrence of earthquakes and volcanoes, and the distribution of fossil plants and animals.

- **Standard 7.2.1** **Develop a model** of the rock cycle to describe the relationship between energy flow and matter cycling that create igneous, sedimentary, and metamorphic rocks. Emphasize the processes of melting, crystallization, weathering, deposition, sedimentation, and deformation, which act together to form minerals and rocks. (ESS1.C, ESS2.A)

- **Standard 7.2.2** **Construct an explanation** based on evidence for how processes have changed Earth's surface at varying time and spatial scales. Examples of processes that occur at varying time scales could include slow plate motions or rapid landslides. Examples of processes that occur at varying spatial scales could include uplift of a mountain range or deposition of fine sediments. (ESS2.A, ESS2.C)

- **Standard 7.2.3** **Ask questions** to *identify constraints of specific* geologic hazards and *evaluate competing design solutions* for maintaining the stability of human-engineered structures, such as homes, roads, and bridges. Examples of geologic hazards could include earthquakes, landslides, or floods. (ESS2.A, ESS2.C, ETS1.A, ETS1.B, ETS1.C)

- **Standard 7.2.4** **Develop and use a scale model** of the matter in the Earth's interior to demonstrate how differences in density and chemical composition (silicon, oxygen, iron, and magnesium) cause the formation of the crust, mantle, and core. (ESS2.A)

- **Standard 7.2.5** **Ask questions** and **analyze and interpret data** about the patterns between plate tectonics and:
  (1) The occurrence of earthquakes and volcanoes.
  (2) Continental and ocean floor features.
  (3) The distribution of rocks and fossils.

  Examples could include identifying patterns on maps of earthquakes and volcanoes relative to plate boundaries, the shapes of the continents, the locations of ocean structures (including mountains, volcanoes, faults, and trenches), or similarities of rock and fossil types on different continents. (ESS1.C, ESS2.B)

- **Standard 7.2.6** **Make an argument from evidence** for how the geologic time scale shows the age and history of Earth. Emphasize scientific evidence from rock strata, the fossil record, and the principles of relative dating, such as superposition, uniformitarianism, and recognizing unconformities. (ESS1.C)

Strand 7.3: STRUCTURE AND FUNCTION OF LIFE

Living things are made of smaller structures, which function to meet the needs of survival. The basic structural unit of all living things is the cell. Parts of a cell work together to function as a system. Cells work together and form tissues, organs, and organ systems. Organ systems interact to meet the needs of the organism.

- **Standard 7.3.1** **Plan and carry out an investigation** that provides evidence that the basic structures of living things are cells. Emphasize that cells can form single-celled or multicellular organisms, and multicellular organisms are made of different types of cells. (LS1.A)
- **Standard 7.3.2** **Develop and use a model** to describe the function of a cell in living systems and the way parts of cells contribute to cell function. Emphasize the cell as a system, including the interrelating roles of the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall. (LS1.A)
- **Standard 7.3.3** **Construct an explanation** using evidence to explain how body systems have various levels of organization. Emphasize that cells form tissues, tissues form organs, and organs form systems specialized for particular body functions. Examples could include relationships between the circulatory, excretory, digestive, respiratory, muscular, skeletal, or nervous systems. Specific organ functions will be taught at the high school level. (LS1.A)

Strand 7.4: REPRODUCTION AND INHERITANCE

The great diversity of species on Earth is a result of genetic variation. Genetic traits are passed from parent to offspring. These traits affect the structure and behavior of organisms, which affect the organism's ability to survive and reproduce. Mutations can cause changes in traits that may affect an organism. As technology has developed, humans have been able to change the inherited traits in organisms, which may have an impact on society.

- **Standard 7.4.1** **Develop and use a model** to explain the effects that different types of reproduction have on genetic variation. Emphasize genetic variation through asexual and sexual reproduction. (LS1.B, LS3.A, LS3.B)
- **Standard 7.4.2** **Obtain, evaluate, and communicate information** about specific animal and plant adaptations and structures that affect the probability of successful reproduction. Examples of adaptations could include nest building to protect young from the cold, herding of animals to protect young from predators, vocalization of animals and colorful plumage to attract mates for breeding, bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, or hard shells on nuts that squirrels bury. (LS1.B)
- **Standard 7.4.3** **Develop and use a model** to describe why genetic mutations may result in harmful, beneficial, or neutral effects to the structure and function of the organism. Emphasize the conceptual idea that changes to traits can happen because of genetic mutations. Specific changes of genes at the molecular level, mechanisms for protein synthesis, and specific types of mutations will be introduced at the high school level. (LS3.A, LS3.B)
- **Standard 7.4.4** **Obtain, evaluate, and communicate information** about the technologies that have changed the way humans affect the inheritance of desired traits in organisms. *Analyze data from tests or simulations to determine the best solution to achieve success* in cultivating selected desired traits in organisms. Examples could include artificial selection, genetic modification, animal husbandry, or gene therapy. (LS4.B, ETS1.A, ETS1.B, ETS1.C)

Strand 7.5: CHANGES IN SPECIES OVER TIME

Genetic variation and the proportion of traits within a population can change over time. These changes can result in evolution through natural selection. Additional evidence of change over time can be found in the fossil record, anatomical similarities and differences between modern and ancient organisms, and embryological development.

- **Standard 7.5.1** **Construct an explanation** that describes how the genetic variation of traits in a population can affect some individuals' probability of surviving and reproducing in a specific environment. Over time, specific traits may increase or decrease in populations. Emphasize the use of proportional reasoning to support explanations of trends in changes to populations over time. Examples could include camouflage, variation of body shape, speed and agility, or drought tolerance. (LS4.B, LS4.C)
- **Standard 7.5.2** **Analyze and interpret data** for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth, under the assumption that natural laws operate today as in the past. (LS4.A, ESS2.E)
- **Standard 7.5.3** **Construct explanations** that describe the patterns of body structure similarities and differences within modern organisms and between ancient and modern organisms to infer possible evolutionary relationships. (LS4.A)
- **Standard 7.5.4** **Analyze data** to compare patterns in the embryological development across multiple species to identify similarities and differences not evident in the fully formed anatomy. (LS4.A)

GRADE 8

INTRODUCTION

The eighth-grade SEEd standards describe the constant interaction of matter and energy in nature. Students will explore how matter is arranged into either simple or complex substances. The strands emphasize how substances store and transfer energy which can cause them to interact physically and chemically, provide energy to living organisms, or be harnessed and used by humans. Matter and energy cycle and change in ecosystems through processes that occur during photosynthesis and cellular respiration. Additionally, substances that provide a benefit to organisms, including humans, are unevenly distributed on Earth due to geologic and atmospheric systems. Some resources form quickly, allowing them to be renewable, while other resources are nonrenewable. Evidence reveals that Earth's systems change and affect ecosystems and organisms in positive and negative ways.

Strand 8.1: MATTER AND ENERGY INTERACT IN THE PHYSICAL WORLD

The physical world is made of atoms and molecules. Even large objects can be viewed as a combination of small particles. Energy causes particles to move and interact physically or chemically. Those interactions create a variety of substances. As molecules undergo a chemical or physical change, the number of atoms in that system remains constant. Humans use energy to refine natural resources into synthetic materials.

- **Standard 8.1.1** **Develop a model** to describe the scale and proportion of atoms and molecules. Emphasize developing atomic models of elements and their numbers of protons, neutrons, and electrons, as well as models of simple molecules. Topics like valence electrons, bond energy, ionic complexes, ions, and isotopes will be introduced at the high school level. (PS1.A)

- **Standard 8.1.2** **Obtain information** about various properties of matter, **evaluate** how different materials' properties allow them to be used for particular functions in society, and **communicate** your findings. Emphasize general properties of matter. Examples could include color, density, flammability, hardness, malleability, odor, ability to rust, solubility, state, or the ability to react with water. (PS1.A)

- **Standard 8.1.3** **Plan and conduct an investigation** and then **analyze and interpret** the **data** to identify patterns in changes in a substance's properties to determine whether a chemical reaction has occurred. Examples could include changes in properties such as color, density, flammability, odor, solubility, or state. (PS1.A, PS1.B)

- **Standard 8.1.4** **Obtain and evaluate information** to describe how synthetic materials come from natural resources, what their functions are, and how society uses these new materials. Examples of synthetic materials could include medicine, foods, building materials, plastics, or alternative fuels. (PS1.A, PS1.B, ESS3.A)

- **Standard 8.1.5** **Develop a model** that uses **computational thinking** to illustrate cause and effect relationships in particle motion, temperature, density, and state of a pure substance when heat energy is added or removed. Emphasize molecular-level models of solids, liquids, and gases to show how adding or removing heat energy can result in phase changes, and focus on calculating the density of a substance's state. (PS3.A)

- **Standard 8.1.6** **Develop a model** to describe how the total number of atoms does not change in a chemical reaction, indicating that matter is conserved. Emphasize demonstrations of an understanding of the law of conservation of matter. Balancing equations and stoichiometry will be learned at the high school level. (PS1.B)

- **Standard 8.1.7** **Design**, construct, and test a device that can affect the rate of a phase change. *Compare and identify the best characteristics of competing devices and modify them based on* ***data analysis*** *to improve the device to better meet the criteria for success*. (PS1.B, PS3.A, ETS1.A, ETS1.B, ETS1.C).

Strand 8.2: ENERGY IS STORED AND TRANSFERRED IN PHYSICAL SYSTEMS

Objects can store and transfer energy within systems. Energy can be transferred between objects, which involves changes in the object's energy. There is a direct relationship between an object's energy, mass, and velocity. Energy can travel in waves and may be harnessed to transmit information.

- **Standard 8.2.1** **Use computational thinking** to **analyze data** about the relationship between the mass and speed of objects and the relative amount of kinetic energy of the objects. Emphasis should be on the quantity of mass and relative speed to the observable effects of the kinetic energy. Examples could include a full cart vs. an empty cart or rolling spheres with different masses down a ramp to measure the effects on stationary masses. Calculations of kinetic and potential energy will be learned at the high school level. (PS3.A)

- **Standard 8.2.2** **Ask questions** about how the amount of potential energy varies as distance within the system changes. **Plan and conduct an investigation** to answer a question about potential energy. Emphasize comparing relative amounts of energy. Examples could include a cart at varying positions on a hill or an object being dropped from different heights. Calculations of kinetic and potential energy will be learned at the high school level. (PS3.A, PS3.C)

- **Standard 8.2.3** **Engage in argument** to identify the strongest evidence that supports the claim that the kinetic energy of an object changes as energy is transferred to or from the object. Examples could include observing temperature changes as a result of friction, applying force to an object, or releasing potential energy from an object. (PS3.A, PS3.B)

- **Standard 8.2.4** **Use computational thinking** to describe a simple model for waves that shows the pattern of wave amplitude being related to wave energy. Emphasize describing waves with both quantitative and qualitative thinking. Examples could include using graphs, charts, computer simulations, or physical models to demonstrate amplitude and energy correlation. (PS4.A)

- **Standard 8.2.5** **Develop and use a model** to describe the structure of waves and how they are reflected, absorbed, or transmitted through various materials. Emphasize both light and mechanical waves. Examples could include drawings, simulations, or written descriptions of light waves through a prism; mechanical waves through gas vs. liquids vs. solids; or sound waves through different mediums. (PS4.A, PS4.B)

- **Standard 8.2.6** **Obtain and evaluate information** to **communicate** the claim that the structure of digital signals are a more reliable way to store or transmit information than analog signals. Emphasize the basic understanding that waves can be used for communication purposes. Examples could include using vinyl record vs. digital song files, film cameras vs. digital cameras, or alcohol thermometers vs. digital thermometers. (PS4.C)

Strand 8.3: LIFE SYSTEMS STORE AND TRANSFER MATTER AND ENERGY

Living things use energy from their environment to rearrange matter to sustain life. Photosynthetic organisms are able to transfer light energy to chemical energy. Consumers can break down complex food molecules to utilize the stored energy and use the particles to form new, life-sustaining molecules. Ecosystems are examples of how energy can flow while matter cycles through the living and nonliving components of systems.

- **Standard 8.3.1** **Plan and conduct an investigation** and use the evidence to **construct an explanation** of how photosynthetic organisms use energy to transform matter. Emphasize molecular and energy transformations during photosynthesis. (PS3.D, LS1.C)
- **Standard 8.3.2** **Develop a model** to describe how food is changed through chemical reactions to form new molecules that support growth and/or release energy as matter cycles through an organism. Emphasize describing that during cellular respiration molecules are broken apart and rearranged into new molecules, and that this process releases energy. (PS3.D, LS1.C)
- **Standard 8.3.3** **Ask questions** to **obtain, evaluate, and communicate information** about how changes to an ecosystem affect the stability of cycling matter and the flow of energy among living and nonliving parts of an ecosystem. Emphasize describing the cycling of matter and flow of energy through the carbon cycle. (LS2.B, LS2.C)

Strand 8.4: INTERACTIONS WITH NATURAL SYSTEMS AND RESOURCES

Interactions of matter and energy through geologic processes have led to the uneven distribution of natural resources. Many of these resources are nonrenewable, and per-capita use can cause positive or negative consequences. Global temperatures change due to various factors, and can cause a change in regional climates. As energy flows through the physical world, natural disasters can occur that affect human life. Humans can study patterns in natural systems to anticipate and forecast some future disasters and work to mitigate the outcomes.

- **Standard 8.4.1** **Construct a** scientific **explanation** based on evidence that shows that the uneven distribution of Earth's mineral, energy, and groundwater resources is caused by geological processes. Examples of uneven distribution of resources could include Utah's unique geologic history that led to the formation and irregular distribution of natural resources like copper, gold, natural gas, oil shale, silver, or uranium. (ESS3.A)

- **Standard 8.4.2** **Engage in argument supported by evidence** about the effect of per-capita consumption of natural resources on Earth's systems. Emphasize that these resources are limited and may be non-renewable. Examples of evidence include rates of consumption of food and natural resources such as freshwater, minerals, or energy sources. (ESS3.A, ESS3.C)

- **Standard 8.4.3** **Design a solution** to monitor or mitigate the potential effects of the use of natural resources. **Evaluate** competing design solutions *using a systematic process to determine how well each solution meets the criteria and constraints of the problem*. Examples of uses of the natural environment could include agriculture, conservation efforts, recreation, solar energy, or water management. (ESS3.A, ESS3.C, ETS1.A, ETS1.B, ETS1.C)

- **Standard 8.4.4** **Analyze and interpret data** on the factors that change global temperatures and their effects on regional climates. Examples of factors could include agricultural activity, changes in solar radiation, fossil fuel use, or volcanic activity. Examples of data could include graphs of the atmospheric levels of gases, seawater levels, ice cap coverage, human activities, or maps of global and regional temperatures. (ESS3.D)

- **Standard 8.4.5** **Analyze and interpret** patterns of the occurrence of natural hazards to forecast future catastrophic events, and investigate how data are used to develop technologies to mitigate their effects. Emphasize how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow prediction, but others, such as earthquakes, may occur without warning. (ESS3.B)

GRADES 9–12
SCIENCE
WITH ENGINEERING EDUCATION (SEEd) STANDARDS
(BIOLOGY, CHEMISTRY, EARTH AND SPACE SCIENCE, AND PHYSICS)

BIOLOGY

INTRODUCTION

The biology SEEd standards explore the patterns, processes, relationships, and the environments of living organisms. Students analyze data on the role of matter cycles and energy flow when organisms interact with their environment to explain how the stability and change of an ecosystem and biodiversity can be affected. Students investigate the structures and functions of living organisms needed in order to support necessary life functions. Students explore the cause and effect relationships of heredity, the role of DNA in gene expression and protein synthesis, and how gene expression can be altered by environmental and genetic causes. Students investigate how the mechanisms of genetic variation can lead to diversity within and among species and explain how the unity among species as well as the great diversity of species is a result of evolution by natural selection. Additionally, students design and evaluate solutions to problems that exist in these areas.

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. 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, altering the ecosystem. Human activities can lead to significant impacts on an ecosystem.

- **Standard BIO.1.1** **Plan and carry out an investigation** to **analyze and interpret data** to determine how biotic and abiotic factors can affect the stability and change of a population. Emphasize stability and change in populations' carrying capacities and an ecosystem's biodiversity. (LS2.A, LS2.C)

- **Standard BIO.1.2** **Develop and use a model** to explain cycling of matter and flow of energy among organisms in an ecosystem. Emphasize the movement of matter and energy through the different living organisms in an ecosystem. Examples of models could include food chains, food webs, energy pyramids or pyramids of biomass. (LS2.B)

- **Standard BIO.1.3** **Analyze and interpret data** to determine the effects of photosynthesis and cellular respiration on the scale and proportion of carbon reservoirs in the carbon cycle. Emphasize the cycling of carbon through the biosphere, atmosphere, hydrosphere, and geosphere and how changes to various reservoirs impact ecosystems. Examples of changes to the scale and proportion of reservoirs could include deforestation, fossil fuel combustion, or ocean uptake of carbon dioxide. (PS3.D, LS1.C, LS2.B)

- **Standard BIO.1.4** **Develop an argument from evidence** for how ecosystems maintain relatively consistent numbers and types of organisms in stable conditions. Emphasize how changing conditions may result in changes to an 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 climate change, volcanic eruption, or sea level rise. (LS2.C)

- **Standard BIO.1.5** **Design a solution** that reduces the impact caused by human activities on the environment and biodiversity. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Examples of human activities could include building dams, pollution, deforestation, or introduction of invasive species. (LS2.C, LS4.D, ETS1.A, ETS1.B, ETS1.C)

Strand BIO.2: STRUCTURE AND FUNCTION OF LIFE

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 organisms. All organisms are made of one or more cells. The structure and function of a cell determines the cell's role in an organism. Multicellular organisms have systems of tissues and organs that work together to meet the needs of the whole organism. Cells grow, divide, and function in order to accomplish essential life processes. Feedback systems help organisms maintain homeostasis.

- **Standard BIO.2.1** **Construct an explanation** based on evidence that all organisms are primarily composed of carbon, hydrogen, oxygen, and nitrogen, and that the matter taken into an organism is broken down and recombined to make macromolecules necessary for life functions. Emphasize that molecules are often transformed through enzymatic processes and the atoms involved are used to make carbohydrates, proteins, fats/lipids, and nucleic acids. (LS1.C)

- **Standard BIO.2.2** **Ask questions** to **plan and carry out an investigation** to determine how (a) the structure and function of cells, (b) the proportion and quantity of organelles, and (c) the shape of cells result in cells with specialized functions. Examples could include mitochondria in muscle and nerve cells, chloroplasts in leaf cells, ribosomes in pancreatic cells, or the shape of nerve cells and muscle cells. (LS1.A)

- **Standard BIO.2.3** **Develop and use a model** to illustrate the cycling of matter and flow of energy through living things by the processes of photosynthesis and cellular respiration. Emphasize how the products of one reaction are the reactants of the other and how the energy transfers in these reactions. (PS3.D, LS1.C, LS2.B)

- **Standard BIO.2.4** **Plan and carry out an investigation** to determine how cells maintain stability within a range of changing conditions by the transport of materials across the cell membrane. Emphasize that large and small particles can pass through the cell membrane to maintain homeostasis. (LS1.A)

- **Standard BIO.2.5** **Construct an explanation** 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. (LS1.B)

(Continued)

■ **Standard BIO.2.6** **Ask questions** to **develop an argument** for how the structure and function of interacting organs and organ systems, that make up multicellular organisms, contribute to homeostasis within the organism. Emphasize the interactions of organs and organ systems with the immune, endocrine, and nervous systems. (LS1.A)

■ **Standard BIO.2.7** **Plan and carry out an investigation** to provide evidence of homeostasis and that feedback mechanisms maintain stability in organisms. Examples of investigations could include heart rate response to changes in activity, stomata response to changes in moisture or temperature, or root development in response to variations in water level. (LS1.A)

Strand BIO.3: GENETIC PATTERNS

Heredity is a unifying biological principle that explains how information is passed from parent to offspring through deoxyribonucleic acid (DNA) molecules in the form of chromosomes. Distinct sequences of DNA, called 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 but may also raise ethical issues.

- **Standard BIO.3.1** **Construct an explanation** for how the structure of DNA is replicated, and how DNA and RNA code for the structure of proteins which regulate and carry out the essential functions of life and result 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 transcription and translation. (LS1.A, LS3.A)

- **Standard BIO.3.2** **Use computational thinking** and patterns to make predictions about the expression of specific traits that are passed in genes on chromosomes from parents to offspring. Emphasize that various inheritance patterns can be predicted by observing the way genes are expressed. Examples of tools to make predictions could include Punnett squares, pedigrees, or karyotypes. Examples of allele crosses could include dominant/recessive, incomplete dominant, codominant, or sex-linked alleles. (LS3.A)

- **Standard BIO.3.3** **Engage in argument from evidence** that inheritable genetic variation is caused during the formation of gametes. Emphasize that genetic variation may be caused by epigenetics, during meiosis from new genetic combinations, or viable mutations. (LS3.B)

- **Standard BIO.3.4** **Plan and carry out an investigation** and **use computational thinking** 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 those traits. Examples of variation and patterns in distribution of traits could include sickle-cell anemia and malaria, hemoglobin levels in humans at high elevation, or antibiotic resistance. (LS3.B)

- **Standard BIO.3.5** Evaluate **design solutions** where biotechnology was used to identify and/or modify genes in order to solve (effect) a problem. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine an optimal solution*. Emphasize arguments that focus on how effective the solution was at meeting the desired outcome. (LS3.B, ETS1.A, ETS1.B, ETS1.C)

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 and changes in selective pressures can cause both speciation and extinction. Changes in environmental conditions impact biodiversity in ecosystems affect the natural selection of species.

- **Standard BIO.4.1** **Obtain, evaluate, and communicate information** to identify the patterns in the evidence that support biological evolution. Examples of evidence could include DNA sequences, amino acid sequences, anatomical structures, the fossil record, or order of appearance of structures during embryological development. (LS4.A)

- **Standard BIO.4.2** **Construct an explanation** based on evidence that natural selection is a primary cause of evolution. Emphasize that natural selection is primarily caused by the potential for a species to increase in number, the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, competition for limited resources, and the proliferation of those organisms that are better able to survive and reproduce in the environment. (LS2.D, LS4.B, LS4.C)

- **Standard BIO.4.3** **Analyze and interpret data** to identify patterns that explain the claim that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. Emphasize analyzing shifts in the numerical distribution of traits and using these shifts as evidence to support explanations. (LS4.B, LS4.C)

- **Standard BIO.4.4** **Engage in argument from evidence** that changes in environmental conditions may cause increases in the number of individuals of some species, the emergence of new species over time, and/or the extinction of other species. Emphasize the cause and effect relationships for how changes and the rate of change to the environment affect distribution or disappearance of traits in a species. Examples of changes in environmental conditions could include deforestation, application of fertilizers, drought, or flood. (LS4.C)

- **Standard BIO.4.5** Evaluate **design solutions** that can best solve a real-world problem caused by natural selection and adaptation of populations. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine an optimal solution*. Examples of real-world problems could include bacterial resistance to drugs, plant resistance to herbicides, or the effect of changes in climate on food sources and pollinators. (LS4.C, ETS1.A, ETS1.B, ETS1.C)

CHEMISTRY

INTRODUCTION

The chemistry SEEd standards explore the foundational principles of chemistry that allow students to investigate the ways in which chemistry impacts everyday life. Students investigate the properties and structure of matter at atomic and subatomic scales to explain how they influence a system's larger scale, structures, properties, and functions. Students explain how macroscopic observations are translated into molecular-level representations and then develop and use these models to describe molecules with chemical equations or mathematical expressions. Students analyze data on the relationships between atomic and molecular structures and the properties of materials that are observed macroscopically using the human senses and scientific instruments. Students explain 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. Additionally, students design and evaluate solutions to problems that exist in these areas.

Strand CHEM.1: THE STRUCTURE AND PROPERTIES OF ATOMS

Atoms have substructures of their own including a small central nucleus containing protons and neutrons surrounded by a larger region containing electrons. The strong nuclear interaction provides the primary force that holds nuclei together. Without it, the electromagnetic forces between protons would make all nuclei other than hydrogen unstable. Processes of fusion, fission, and radioactive decay of unstable nuclei involve changes in nuclear binding energies. Elements are placed in columns and rows on the periodic table to reflect their common and repeating properties.

- **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 electrons in atoms. Examples of experimental evidence could include the gold foil experiment, cathode ray tube, or atomic spectrum data. (PS1.A)

- **Standard CHEM.1.2** **Analyze and interpret data** to identify patterns in the stability of isotopes and predict likely modes of radioactive decay. Emphasize that different isotopes of the same element decay by different modes and at different rates depending on their nuclear stability. Examples of data could include band of stability charts, mass or nuclear binding energy per nucleon, or the inverse relationship between half-life and nuclear stability. (PS1.C)

- **Standard CHEM.1.3** **Use mathematics and computational thinking** to relate the rates of change in quantities of radioactive isotopes through radioactive decay (alpha, beta, and positron) to ages of materials or persistence in the environment. Emphasize a conceptual understanding of half-life. Examples could include radiocarbon dating, nuclear waste management, or nuclear medicine. (PS1.C)

- **Standard CHEM.1.4** **Construct an explanation** about how fusion can form new elements with greater or lesser nuclear stability. Emphasize the nuclear binding energy, with the conceptual understanding that when fusion of elements results in a more stable nucleus, large quantities of energy are released, and when fusion results in a less stable nucleus, large quantities of energy are required. Examples could include the building up of elements in the universe starting with hydrogen to form heavier elements, the composition of stars, or supernovae producing heavy elements. (PS1.C, ESS1.A)

- **Standard CHEM.1.5** **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, or electronegativity. Examples of properties for main group elements could include general reactivity, bonding type, or ion formation. (PS1.A)

Strand CHEM.2: THE STRUCTURE AND PROPERTIES OF MOLECULES

Electrical attractions and repulsions between charged particles (atomic nuclei and electrons) in matter explain the structure of atoms and the forces between atoms that cause them to form molecules via chemical bonds. Molecules can range in size from two atoms to thousands of atoms. The same forces cause atoms to combine to form extended structures, such as crystals or metals. The varied properties of the materials, both natural and manufactured, can be understood in terms of the atomic and molecular particles present and the forces within and between them. Materials are engineered to fulfill a desired function or role with desired properties.

- **Standard CHEM.2.1** **Analyze data** to predict the type of bonding 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 in ionic, covalent, and metallic bonds. 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. (PS1.A, PS2.B)

- **Standard CHEM.2.2** **Plan and carry out an investigation** to compare the properties of substances at the bulk scale and relate them to molecular structures. Emphasize using models to explain or describe the strength of electrical forces between particles. Examples of models could include Lewis dot structures or ball and stick models. Examples of particles could include ions, atoms, molecules, or networked materials (such as graphite). Examples of properties could include melting point and boiling point, vapor pressure, solubility, or surface tension. (PS1.A)

- **Standard CHEM.2.3** **Engage in argument supported by evidence** that the functions of natural and designed macromolecules are related to their chemical structures. Emphasize the roles of attractive forces between and within molecules. Examples could include non-covalent interactions between base pairs in DNA allowing it to be unzipped for replication, the network of atoms in a diamond conferring hardness, or the nonpolar nature of polyester (PET) making it quick-drying. (PS1.A)

- **Standard CHEM.2.4** Evaluate **design solutions** where synthetic chemistry was used to solve a problem (cause and effect). *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine an optimal solution*. Emphasize the design of materials to control their properties through chemistry. Examples could include pharmaceuticals that target active sites, teflon to reduce friction on surfaces, or nanoparticles of zinc oxide to create transparent sunscreen. (PS1.A, ETS1.A, ETS1.B, ETS1.C)

Strand CHEM.3: STABILITY AND CHANGE IN CHEMICAL SYSTEMS

Conservation of matter describes the cycling of matter and the use of resources. In both chemical and physical changes, the total number of each type of atom is conserved. When substances are combined, they may interact with each other to form a solution. 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 may have different properties. 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** **Use mathematics and computational thinking** to analyze the distribution and proportion of particles in solution. Emphasize proportional reasoning and the impact of concentration on solution properties, rather than algorithmic calculations. Examples of concentrations affecting solutions could include the Beer-Lambert Law, colligative properties, or pH. (PS1.A)

- **Standard CHEM.3.2** **Analyze data** to identify patterns that assist in making predictions of the outcomes of simple chemical reactions. Emphasize patterns based on the outermost electrons of atoms, trends in the periodic table, and knowledge of chemical properties. Examples could include reactions between main group elements, combustion reactions, or reactions between Arrhenius acids and bases. (PS1.B)

- **Standard CHEM.3.3** **Plan and carry out an investigation** to observe the change in properties of substances in a chemical reaction to relate the macroscopically observed properties to the molecular level changes in bonds 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 of observable properties could include changes in color or the production of a solid or gaseous product. (PS1.B)

- **Standard CHEM.3.4** **Use mathematics and computational thinking** to support the observation that matter is conserved during chemical reactions and matter cycles. Emphasize that chemical reactions occur on both small and global scales, and that matter is always conserved. Examples of small scale reactions could include ratios of reactants and products in a single chemical reaction or simple stoichiometric calculation. Examples of global scale matter cycles could include tracing carbon through the chemical reactions of photosynthesis, combustion, or respiration. (PS1.B)

■ **Standard CHEM.3.5** **Develop solutions** related to the management, conservation, and utilization of mineral resources (matter). *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Emphasize the conservation of matter and minerals as a limited resource. Examples of Utah mineral resources could include copper, uranium, potash, coal, oil, or natural gas. Examples of constraints could include cost, safety, reliability, or possible social, cultural, and environmental impacts. (PS1.B, ESS3.A, ETS1.A, ETS1.B, ETS1.C)

■ **Standard CHEM.3.6** **Construct an explanation** using experimental evidence for how 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. (PS1.B)

■ **Standard CHEM.3.7** **Design a solution** that would refine a chemical system by specifying a change in conditions that would produce increased or decreased amounts of a product at equilibrium. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Emphasize a qualitative understanding of Le Châtelier’s Principle and connections between macroscopic and molecular level changes. (PS1.B, ETS1.A, ETS1.B, ETS1.C)

■ **Standard CHEM.3.8** **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, DDT, development of medicines, the preservation of historical artifacts, or use of bisphenol-A in plastic manufacturing. (PS1.A)

Strand CHEM.4: ENERGY IN CHEMICAL SYSTEMS

A system's total energy is conserved as energy is continually transferred from one particle to another and between its various possible forms. 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. When electromagnetic radiation with longer wavelengths is absorbed by matter, it is generally converted into thermal energy or heat. When visible light is absorbed by matter, it results in phenomena related to color. When shorter wavelength electromagnetic radiation is absorbed by matter, it can ionize atoms and cause damage to living cells. Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve the 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 energy. Emphasize that the overall change in energy is related to the energy absorbed when bonds are broken and the energy released when bonds are formed. Examples could include chemical reactions releasing or absorbing energy to or from the surrounding solution or the metabolism of glucose. (PS1.B, PS3.B)

- **Standard CHEM.4.2** **Construct an explanation** of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. Emphasize a qualitative understanding. Examples could include that low energy electromagnetic radiation can increase molecular rotation and bond vibration, visible light can cause electronic transitions, and high energy electromagnetic radiation can result in ionization and bond breaking. (PS4.B)

- **Standard CHEM.4.3** **Design** a device that converts energy from one form into another to solve a problem. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Emphasize chemical potential energy as a type of stored energy. Examples of sources of chemical potential energy could include oxidation-reduction or combustion reactions. (PS3.B, ETS1.A, ETS1.B, ETS1.C)

- **Standard CHEM.4.4** **Use models** to describe the changes in the composition of the nucleus of the atom during nuclear processes, and compare the energy 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. (PS1.C, PS3.D)

■ **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*. (PS3.D, ETS1.A, ETS1.B, ETS1.C)

EARTH AND SPACE SCIENCE

INTRODUCTION

The Earth and space science SEEd Standards investigate processes and mechanisms that have resulted in the formation of our Earth, galaxy, and universe. Students develop models to illustrate the life span of the Sun and the role of nuclear fusion releasing energy in the Sun's core. Students analyze and interpret data to construct an explanation for Earth's 4.6 billion year history and explore changes to Earth's systems. Students develop and use a model of Earth's interior to describe the cycling of matter by thermal convection. Students plan and carry out an investigation on the properties of water to determine its effects on Earth materials. Students use computational thinking to explain sustainable and natural resources, focusing on responsible stewardship. Additionally, students design and evaluate solutions to problems that exist in these areas.

Strand ESS.1: MATTER AND ENERGY IN SPACE

The Sun releases energy that eventually reaches Earth in the form of electromagnetic radiation. The Big Bang theory is supported by observations of distant galaxies receding from our own as well as other evidence. The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, releasing electromagnetic energy. Heavier elements are produced when certain massive stars reach a supernova stage and explode. New technologies advance science knowledge including space exploration.

- **Standard ESS.1.1** **Develop a model** based on evidence to illustrate the life span of the Sun and the role of nuclear fusion releasing energy in the Sun's core. Emphasize energy transfer mechanisms that allow energy from nuclear fusion to reach Earth. Examples of evidence for the model could include observations of the masses and lifetimes of other stars, or non-cyclic variations over centuries. (PS1.C, PS3.D, ESS1.A, ESS1.B)

- **Standard ESS.1.2** **Construct an explanation** of the Big Bang theory based on astronomical evidence of electromagnetic radiation, motion of distant galaxies, and composition of matter in the universe. Emphasize redshift of electromagnetic radiation, cosmic microwave background radiation, and the observed composition and distribution of matter in the universe. (PS4.B, ESS1.A)

- **Standard ESS.1.3** **Develop a model** to illustrate the changes in matter occurring in a star's life cycle. Emphasize that the way different elements are created varies as a function of the mass of a star and the stage of its lifetime. (PS3.D, ESS1.A)

- **Standard ESS.1.4** **Design a solution** to a space exploration challenge by *breaking it down into smaller, more manageable problems that can be solved through the* structure and function of *a device. Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Examples of problems could include, cosmic radiation exposure, transportation on other planets or moons, or supplying energy to space travelers. (ESS1.A, ESS1.B, ETS1.A, ETS1.B, ETS1.C)

Strand ESS.2: PATTERNS IN EARTH'S HISTORY AND PROCESSES

Although active geologic processes have destroyed or altered most of Earth's early rock record, evidence from within Earth and from other objects in the solar system are used to infer Earth's geologic history. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history and co-evolution of life.

- **Standard ESS.2.1** **Analyze and interpret data** to construct an explanation for the changes in Earth's formation and 4.6 billion year history. Examples of data could include the absolute ages of ancient Earth materials, the size and composition of solar system objects like meteorites, or the impact cratering record of planetary surfaces. (ESS1.C)

- **Standard ESS.2.2** **Develop and use a model** based on evidence of Earth's interior and describe the cycling of matter by thermal convection. Emphasize the density of Earth's layers and mantle convection driven by radioactive decay and heat from Earth's early formation. Examples of evidence could include maps of Earth's three-dimensional structure obtained from seismic waves or records of the rate of change of Earth's magnetic field. (PS1.C, ESS2.A, ESS2.B)

- **Standard ESS.2.3** **Construct an explanation** for how plate tectonics results in patterns on Earth's surface. Emphasize past and current plate motions. Examples could include continental and ocean floor features such as mountain ranges and mid-ocean ridges, magnetic polarity preserved in seafloor rocks, or regional hot spots. (ESS2.B)

- **Standard ESS.2.4** **Develop and use a model** to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales. Emphasize how the appearance of land and seafloor features are a result of both constructive forces and destructive mechanisms. Examples of constructive forces could include tectonic uplift or mountain building. Examples of destructive mechanisms could include weathering or mass wasting. (ESS2.B)

(Continued)

- **Standard ESS.2.5** **Engage in argument from evidence** for how the simultaneous co-evolution of Earth's systems and life on Earth led to periods of stability and change over geologic time. Examples could include how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants or how the evolution of corals created reefs that altered patterns of coastal erosion and deposition providing habitats for the evolution of new life forms. (LS4.D, ESS2.D, ESS2.E)

- **Standard ESS.2.6** Evaluate **design solutions** that reduce the effects of natural disasters on humans. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine an optimal solution*. Examples of natural disasters could include earthquakes, tsunamis, hurricanes, drought, landslides, floods, or wildfires. (ESS3.B, ETS1.A, ETS1.B, ETS1.C)

Strand ESS.3: SYSTEM INTERACTIONS: ATMOSPHERE, HYDROSPHERE, AND GEOSPHERE

The abundance of liquid water on Earth's surface and its unique properties are central to the planet's dynamics and system interactions. The foundation for Earth's global weather and climate systems is electromagnetic radiation from the Sun. The ocean exerts a major influence on weather and climate by absorbing energy from the Sun, releasing it over time, and globally redistributing it through ocean currents. Changes in the atmosphere due to human activity increase carbon dioxide concentrations and thus affect climate. Current scientific models predict that future average global temperatures will continue to rise, although regional climate changes will be complex and varied.

- **Standard ESS.3.1** **Plan and carry out an investigation** of the properties of water and its effects on Earth materials and surface processes. Examples of properties could include water's capacity to expand upon freezing, dissolve and transport material, or absorb, store, and release energy. (ESS2.C)

- **Standard ESS.3.2** **Construct an explanation** of how heat (energy) and water (matter) move throughout the oceans causing patterns in weather and climate. Emphasize the mechanisms for surface and deep ocean movement. Examples of mechanisms for surface movement could include wind, Sun's energy, or the Coriolis effect. Examples of mechanisms for deep ocean movement could include water density differences due to temperature or salinity. (ESS2.C, ESS2.D)

- **Standard ESS.3.3** **Construct an explanation** for how energy from the Sun drives atmospheric processes and how atmospheric currents transport matter and transfer energy. Emphasize how energy from the Sun is reflected, absorbed, or scattered; how the greenhouse effect contributes to atmospheric energy; and how uneven heating of Earth's atmosphere combined with the Coriolis effect creates an atmospheric circulation system. (PS3.A, ESS1.B, ESS2.A, ESS2.D)

- **Standard ESS.3.4** **Analyze and interpret** patterns in **data** about the factors influencing weather of a given location. Emphasize the amount of solar energy received due to latitude, elevation, the proximity to mountains and/or large bodies of water, air mass formation and movement, and air pressure gradients. (ESS2.D)

(Continued)

- **Standard ESS.3.5** **Develop and use** a quantitative **model** to describe the cycling of carbon among Earth's systems. Emphasize each of Earth's systems (hydrosphere, atmosphere, geosphere, and biosphere) and 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. (LS2.B, ESS2.D, ESS3.D)

- **Standard ESS.3.6** **Analyze and interpret data** from global climate records to illustrate changes to Earth's systems throughout geologic time and make predictions about future variations using modern trends. Examples of data could include average sea surface temperature, average air temperature, composition of gasses in ice cores, or tree rings. (ESS2.D, ESS3.D)

- **Standard ESS.3.7** **Engage in argument from evidence** to support the claim that one change to Earth's surface can create climate feedback loops that cause changes to other systems. Examples of climate feedbacks could include ice-albedo or warming oceans. (PS3.B, ESS2.A)

Strand ESS.4: STABILITY AND CHANGE IN NATURAL RESOURCES

Humans depend on Earth's systems for many different resources, including air, water, minerals, metals, and energy. Resource availability has guided the development of human society and is constantly changing due to societal needs. Natural hazards and other geologic events have shaped the course of human history. The sustainability of human societies, and the biodiversity that supports them, requires responsible management of natural resources. Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that reduce ecosystem degradation. They also evaluate solutions to resolve complex global and localized problems that contain inherent social, cultural, and environmental impacts in an effort to improve the quality of life for all.

- **Standard ESS.4.1** **Construct an explanation** for how the availability of natural resources, the occurrence of natural hazards, and changes in climate affect human activity. Examples of natural resources could include access to fresh water, clean air, or regions of fertile soils. Examples of factors that affect human activity could include that rising sea levels cause humans to move farther from the coast or that humans build railroads to transport mineral resources from one location to another. (ESS3.A, ESS3.B)

- **Standard ESS.4.2** **Use computational thinking** to explain the relationships between the sustainability of natural resources and biodiversity within Earth systems. Emphasize the importance of responsible stewardship of Earth's resources. Examples of factors related to sustainability could include costs of resource extraction, per-capita consumption, waste management, agricultural efficiency, or levels of conservation. Examples of natural resources could include minerals, water, or energy resources. (ESS3.A)

- **Standard ESS.4.3** Evaluate **design solutions** for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios on large and small scales. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine an optimal solution*. Emphasize the conservation, recycling, and reuse of resources where possible and minimizing impact where it is not possible. Examples of large-scale solutions could include developing best practices for agricultural soil use or mining and production of conventional, unconventional, or renewable energy resources. Examples of small-scale solutions could include mulching lawn clippings or adding biomass to gardens. (ESS3.A, ETS1.A, ETS1.B, ETS1.C)

- **Standard ESS.4.4** Evaluate **design solutions** for a major global or local environmental problem based on one of Earth's systems. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine an optimal solution*. Examples of major global or local problems could include water pollution or availability, air pollution, deforestation, or energy production. (ESS3.C, ETS1.A, ETS1.B, ETS1.C)

PHYSICS

INTRODUCTION

The physics SEEd standards explore the foundational principles of physics including forces, energy, fields, and waves. Students analyze and interpret data to determine the cause and effect relationship between the net force of an object and its change in motion. Students develop and use models to illustrate that energy at all levels can be accounted for as a combination of energies associated with motion and relative positions of objects. Students use mathematics and computational thinking to support the claim that the total momentum of a system is conserved when there is no net force acting on a system. Students plan and conduct investigations to provide evidence that an electric current causes a magnetic field and that a changing magnetic field causes an electric current. Students also engage in argument to support the assertion that electromagnetic radiation can be described either by a wave or a particle model. Additionally, students design and evaluate solutions to problems that exist in these areas.

Strand PHYS.1: FORCES AND INTERACTIONS

Uniform motion of an object is natural. Changes in motion are caused by a nonzero sum of forces. A "net force" causes an acceleration as predicted by Newton's 2nd Law. Qualitative and quantitative analysis of position, velocity, and acceleration provide evidence of the effects of forces. Momentum is defined for a particular frame of reference; it is the product of the mass and the velocity of the object. In any system, total momentum is always conserved. If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. The time over which these paired forces are exerted determines the impact force.

■ **Standard PHYS.1.1** **Analyze and interpret data** to determine the cause and effect relationship between the net force on an object and its change in motion as summarized by Newton's Second Law of Motion. Emphasize one-dimensional motion and 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. (PS2.A)

■ **Standard PHYS.1.2** **Use mathematics and computational thinking** to support the claim that the total momentum of a system is conserved when there is no net force acting on the system. Emphasize the quantitative conservation of momentum in interactions and the qualitative meaning of this principle. Examples could include one-dimensional elastic or inelastic collisions between objects within the system. (PS2.A)

■ **Standard PHYS.1.3** **Design a solution** that has the function of minimizing the impact force on an object during a collision. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Emphasize problems that require application of Newton's Second Law of Motion or conservation of momentum. (PS2.A, ETS1.A, ETS1.B, ETS1.C)

Strand PHYS.2: ENERGY

Energy describes the motion and interactions of matter and radiation within a system. Energy is a quantifiable property that is conserved in isolated systems and in the universe as a whole. At the macroscopic scale, energy manifests itself in multiple ways such as in motion, sound, light, and thermal energy. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution. Examining the world through an energy lens allows us to model and predict complex interactions of multiple objects within a system and address societal needs.

- **Standard PHYS.2.1** **Analyze and interpret data** to track and calculate the transfer of energy within a system. Emphasize the identification of the components of the system, along with their initial and final energies, and mathematical descriptions to depict energy transfer in the system. Examples of energy transfer could include the transfer of energy during a collision or heat transfer. (PS3.A, PS3.B)

- **Standard PHYS.2.2** **Plan and conduct an investigation** to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system. Emphasize that uniform distribution of energy is a natural tendency. Examples could include the measurement of the reduction of temperature of a hot object or the increase in temperature of a cold object. (PS3.B)

- **Standard PHYS.2.3** **Develop and use models** on the macroscopic scale to illustrate that energy 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 is conserved. Examples could include mechanical systems where kinetic energy is transformed to potential energy or vice versa. (PS3.A)

- **Standard PHYS.2.4** **Design a solution** by constructing a device that converts one form of energy into another form of energy to solve a complex real-life problem. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Examples of energy transformation could include electrical energy to mechanical energy, mechanical energy to electrical energy, or electromagnetic radiation to thermal energy. (PS3.A, PS3.B, ETS1.A, ETS1.B, ETS1.C)

(Continued)

■ **Standard PHYS 2.5** **Design a solution** to a major global problem that accounts for societal energy needs and wants. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Emphasize problems that require the application of conservation of energy principles through energy transfers and transformations. Examples of devices could include one that uses renewable energy resources to perform functions currently performed by nonrenewable fuels or ones that are more energy efficient to conserve energy. (PS3.A, PS3.B, PS3.D, ETS1.A, ETS1.B, ETS1.C)

Strand PHYS.3: FIELDS

Fields describe how forces act through space and how potential energy is stored in systems. These take on different forms of electric, magnetic, or gravitational fields, but similarly provide a mechanism for how matter interacts. When two objects interacting through a field change relative position, the energy stored in the field is changed. These fields are important at a wide variety of scales, ranging from the subatomic to the astronomic.

- **Standard PHYS.3.1** **Use mathematics and computational thinking** to compare the scale and proportion of gravitational and electric fields using Newton's Law of Gravitation and Coulomb's Law. Emphasize the comparative strength of these two field forces, the effect of distance between interacting objects on the magnitudes of these forces, and the use of models to understand field forces. (PS2.B)

- **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 electromagnets or generators. (PS2.C)

- **Standard PHYS.3.3** **Analyze and interpret data** to compare the effect of changes in position of interacting objects on electric and gravitational forces and energy. Emphasize the similarities and differences between charged particles in electric fields and masses in gravitational fields. Examples could include models, simulations, or experiments that produce data or illustrate field lines between objects. (PS3.C)

- **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 of electric fields could include those resulting from point charges. Examples of magnetic fields could include those resulting from dipole magnets or current-bearing wires. (PS3.C)

Strand PHYS.4: WAVES

Waves transfer energy through oscillations of fields or matter. The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it passes. Waves produce interference as they overlap but they emerge unaffected by each other. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy. 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** to derive both qualitative and quantitative relationships based on patterns observed in frequency, wavelength, and speed of waves traveling in various media. Emphasize mathematical relationships and qualitative descriptions. Examples of data could include electromagnetic radiation traveling in a vacuum or glass, sound waves traveling through air or water, or seismic waves traveling through Earth. (PS4.A)

- **Standard PHYS.4.2** **Engage in argument based on evidence** that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model better explains interactions within a system 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, or the photoelectric effect. (PS4.A, PS4.B)

- **Standard PHYS.4.3** **Evaluate information** about the effects that different frequencies of electromagnetic radiation have when absorbed by biological materials. Emphasize that the energy of electromagnetic radiation is directly proportional to frequency and that the potential damage to living tissue from electromagnetic radiation depends on the energy of the radiation. (PS4.B)

- **Standard PHYS.4.4** **Ask questions** and **construct an explanation** about the stability of digital transmission and storage of information and their impacts on society. Emphasize the stability of digital signals and the discrete nature of information transmission. Examples of stability and instability could include that digital information can be stored in computer memory, is transferred easily, copied and shared rapidly can be easily deleted, has limited fidelity based on sampling rates, or is vulnerable to security breaches and theft. (PS4.A)

■ **Standard PHYS.4.5** **Obtain, evaluate, and communicate information** about how devices use the principles of electromagnetic radiation and their interactions with matter to transmit and capture information and energy. Emphasize the ways in which devices leverage the wave-particle duality of electromagnetic radiation. Examples could include solar cells, medical imaging devices, or communication technologies. (PS4.A, PS4.B, PS4.C)

UTAH HIGH SCHOOL SUPPLEMENTAL

SEEd Standards

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INTRODUCTION

UTAH HIGH SCHOOL SUPPLEMENTAL SCIENCE WITH ENGINEERING EDUCATION STANDARDS

Utah's High School Supplemental Science and Engineering Education (SEEd) standards were written with support from Utah educators and scientists, using a wide array of resources and expertise. A great deal is known about good science instruction. The writing team used sources including *A Framework for K–12 Science Education*[1], the *Science Georgia Standards of Excellence (GSE)*[2], and related works to craft research-based standards for Utah. These standards were written with high school students in mind to provide them with developmentally appropriate learning that extends from the Utah foundation SEEd Standards in Biology, Chemistry, Earth and Space Science, and Physics. These courses are intended to foster learning that is age-appropriate and enduring with the aim of addressing what an educated citizenry should know and understand to embrace the value of scientific thinking and make informed decisions. All Utah SEEd standards are founded on what science is, how science is learned, and the multiple dimensions of scientific work.

As these high school science supplemental courses are taught in both semester and yearlong formats, the standards were written to be able to be taught in a semester. Educators teaching these as yearlong courses will be able to expand them to meet the needs of their students. Teaching these courses as a semester or yearlong format is a local school or district decision.

Principles of Scientific Literacy

Science is a way of knowing, a process for understanding the natural world. Engineering applies the fields of science, technology, and mathematics to produce solutions to real-world problems. The process of developing scientific knowledge includes ongoing questioning, testing, and refinement of ideas when supported by empirical evidence. Since progress in modern society is tied so closely to this way of knowing, scientific literacy is essential for a society to be engaged in political and economic choices on personal, local, regional, and global scales. As such, the Utah SEEd standards are based on the following essential elements of scientific literacy.

Science is valuable, relevant, and applicable.
Science produces knowledge that is inherently important to our society and culture. Science and engineering support innovation and enhance the lives of individuals and society. Science is supported from and benefited by an equitable and democratic culture. Science is for all people, at all levels of education, and from all backgrounds.

Science is a shared way of knowing and doing.
Science learning experiences should celebrate curiosity, wonder, skepticism, precision,

and accuracy. Scientific habits of mind include questioning, communicating, reasoning, analyzing, collaborating, and thinking critically. These values are shared within and across scientific disciplines, and should be embraced by students, teachers, and society at large.

Science is principled and enduring.
Scientific knowledge is constructed from empirical evidence; therefore, it is both changeable and durable. Science is based on observations and inferences, an understanding of scientific laws and theories, use of scientific methods, creativity, and collaboration. The Utah SEEd standards are based on current scientific theories, which are powerful and broad explanations of a wide range of phenomena; they are not simply guesses nor are they unchangeable facts.

Science is principled in that it is limited to observable evidence. Science is also enduring in that theories are only accepted when they are robustly supported by multiple lines of peer reviewed evidence. The history of science demonstrates how scientific knowledge can change and progress, and it is rooted in the cultures from which it emerged. Scientists, engineers, and society, are responsible for developing scientific understandings with integrity, supporting claims with existing and new evidence, interpreting competing explanations of phenomena, changing models purposefully, and finding applications that are ethical.

Principles of Science Learning

Just as science is an active endeavor, students best learn science by engaging in it. This includes gathering information through observations, reasoning, and communicating with others. It is not enough for students to read about or watch science from a distance; learners must become active participants in forming their ideas and engaging in scientific practice. The Utah SEEd standards are based on several core philosophical and research-based underpinnings of science learning.

Science learning is personal and engaging.
Research in science education supports the assertion that students at all levels learn most when they are able to construct and reflect upon their ideas, both by themselves and in collaboration with others. Learning is not merely an act of retaining information but creating ideas informed by evidence and linked to previous ideas and experiences. Therefore, the most productive learning settings engage students in authentic experiences with natural phenomena or problems to be solved. Learners develop tools for understanding as they look for patterns, develop explanations, and communicate with others. Science education is most effective when learners invest in their own sense-making and their learning context provides an opportunity to engage with real-world problems.

Science learning is multi-purposed.
Science learning serves many purposes. We learn science because it brings us joy and appreciation but also because it solves problems, expands understanding, and informs

society. It allows us to make predictions, improve our world, and mitigate challenges. An understanding of science and how it works is necessary in order to participate in a democratic society. So, not only is science a tool to be used by the future engineer or lab scientist but also by every citizen, every artist, and every other human who shares an appreciation for the world in which we live.

All students are capable of science learning.
Science learning is a right of all individuals and must be accessible to all students in equitable ways. Independent of grade level, geography, gender, economic status, cultural background, or any other demographic descriptor, all K–12 students are capable of science learning and science literacy. Science learning is most equitable when students have agency and can engage in practices of science and sense-making for themselves, under the guidance and mentoring of an effective teacher and within an environment that puts student experience at the center of instruction. Moreover, all students are capable learners of science, and all grades and classes should provide authentic, developmentally appropriate science instruction.

Three Dimensions of Science

Science is composed of multiple types of knowledge and tools. These include the processes of doing science, the structures that help us organize and connect our understandings, and the deep explanatory pieces of knowledge that provide predictive power. These facets of science are represented as "three dimensions" of science learning, and together these help us to make sense of all that science does and represents. These include science and engineering practices, crosscutting concepts, and disciplinary core ideas. Taken together, these represent how we use science to make sense of phenomena, and they are most meaningful when learned in concert with one another. These are described in *A Framework for K–12 Science Education*, referenced above, and briefly described here:

Science and Engineering Practices (SEPs): Practices refer to the things that scientists and engineers do and how they actively engage in their work. Scientists do much more than make hypotheses and test them with experiments. They engage in wonder, design, modeling, construction, communication, and collaboration. The practices describe the variety of activities that are necessary to do science, and they also imply how scientific thinking is related to thinking in other subjects, including math, writing, and the arts. For a further understanding of science and engineering practices see Chapter 3 in *A Framework for K–12 Science Education*.

Crosscutting Concepts (CCCs): Crosscutting concepts are the organizing structures that provide a framework for assembling pieces of scientific knowledge. They reach across disciplines and demonstrate how specific ideas are united into overarching principles. For example, a mechanical engineer might design some process that transfers energy from a fuel source into a moving part, while a biologist might study how predators and prey are interrelated. Both of these would need to model systems of energy to understand how all of the features interact, even though they are studying different subjects. Understanding crosscutting concepts enables us to make connections among different subjects and to utilize science in diverse settings. Additional information on crosscutting concepts can be found in Chapter 4 of *A Framework for K–12 Science Education*.

Disciplinary Core Ideas (DCIs): Core ideas within the foundation High School SEEd Standards for Biology, Chemistry, Earth and Space Science, and Physics include those most fundamental and explanatory pieces of knowledge in a discipline. They are often what we traditionally associate with science knowledge and specific subject areas within science. Seeing as how the High School Supplemental Standards are an extension of the foundation High School courses, the content in these standards move beyond those identified as Disciplinary Core Ideas in Chapters 5 through 7 of *A Framework for K–12 Science Education*. The standards within this document with a specific focus on engineering are closely aligned to the Core Ideas found in Chapter 8 of the *K–12 Framework for K–12 Science Education*. For this reason, the Disciplinary Core Idea Codes (listed in parentheses after each standard in the foundation High School SEEd Standards) will not be included in these standards.

ARTICULATION OF SEPS, CCCS, AND DCIS

Science and Engineering Practices

Asking questions or defining problems: Students engage in asking testable questions and defining problems to pursue understandings of phenomena.

Developing and using models: Students develop physical, conceptual, and other models to represent relationships, explain mechanisms, and predict outcomes.

Planning and carrying out investigations: Students plan and conduct scientific investigations in order to test, revise, or develop explanations.

Analyzing and interpreting data: Students analyze various types of data in order to create valid interpretations or to assess claims/conclusions.

Using mathematics and computational thinking: Students use fundamental tools in science to compute relationships and interpret results.

Constructing explanations and designing solutions: Students construct explanations about the world and design solutions to problems using observations that are consistent with current evidence and scientific principles.

Engaging in argument from evidence: Students support their best explanations with lines of reasoning using evidence to defend their claims.

Obtaining, evaluating, and communicating information: Students obtain, evaluate, and derive meaning from scientific information or presented evidence using appropriate scientific language. They communicate their findings clearly and persuasively in a variety of ways including written text, graphs, diagrams, charts, tables, or orally.

Crosscutting Concepts

Patterns:
Students observe patterns to organize and classify factors that influence relationships.

Cause and effect:
Students investigate and explain causal relationships in order to make tests and predictions.

Scale, proportion, and quantity:
Students compare the scale, proportions, and quantities of measurements within and between various systems.

Systems and system models:
Students use models to explain the parameters and relationships that describe complex systems.

Energy and matter:
Students describe cycling of matter and flow of energy through systems, including transfer, transformation, and conservation of energy and matter.

Structure and function:
Students relate the shape and structure of an object or living thing to its properties and functions.

Stability and change:
Students evaluate how and why a natural or constructed system can change or remain stable over time.

Disciplinary Core Ideas*

Physical Sciences:
(PS1) Matter and Its Interactions
(PS2) Motion and Stability: Forces and Interactions
(PS3) Energy
(PS4) Waves

Life Sciences:
(LS1) Molecules to Organisms
(LS2) Ecosystems
(LS3) Heredity
(LS4) Biological Evolution

Earth and Space Sciences:
(ESS1) Earth's Place in the Universe
(ESS2) Earth's Systems
(ESS3) Earth and Human Activity

Engineering Design:
(ETS1.A) Defining and Delimiting an Engineering Problem
(ETS1.B) Developing Possible Solutions
(ETS1.C) Optimizing the Design Solution

** These core ideas are specifically aligned in each of the standards for Biology, Chemistry, Earth and Space Science, and Physics courses, however these High School Supplemental SEEd Standards focus on content beyond these core ideas and direct alignment will not be made within the standards document.*

See the appendix for more information about the three dimensions.

Organization of Standards

The Utah SEEd standards are organized into **strands** which represent significant areas of learning within grade level progressions and content areas. Each strand introduction is an orientation for the teacher in order to provide an overall view of the concepts needed for foundational understanding. These include descriptions of how the standards tie together thematically and science content is used to unite that theme. Within each strand are **standards**. A standard is an articulation of how a learner may demonstrate their proficiency, incorporating not science content but also a crosscutting concept and a science and engineering practice. While a standard represents an essential element of what is expected, it does not dictate curriculum—it only represents a proficiency level for that grade. While some standards within a strand may be more comprehensive than others, all standards are essential for a comprehensive understanding of a strand's purpose.

The standards of any given grade or course are not independent. SEEd standards are written with developmental levels and learning progressions in mind so that many topics are built upon from one grade to another. In addition, SEPs and CCCs are especially well paralleled with other disciplines, including English language arts, fine arts, mathematics, and social sciences. Therefore, SEEd standards should be considered to exist not as an island unto themselves, but as a part of an integrated, comprehensive, and holistic educational experience.

Each standard is framed upon the three dimensions of science to represent a cohesive, multi-faceted science learning outcome.

- Within each SEEd Standard **Science and Engineering Practices are bolded**.
- <u>Crosscutting Concepts are underlined</u>.
- Science content including and extending from the Disciplinary Core Ideas are added to the standard in normal font. The Disciplinary Core Idea Codes (listed in parentheses after each standard in the foundation High School SEEd Standards) are not included in these standards.
- Standards with *specific engineering expectations are italicized*.
- Many standards contain additional emphasis and example statements that clarify the learning goals for students.
  - Emphasis statements highlight a required and necessary part of the student learning to satisfy that standard.
  - Example statements help to clarify the meaning of the standard and are not required for instruction.

An example of a SEEd standard:

- **Standard ENVS.3.4** **Design a solution** in the form of a resource management plan to sustain (stability) a natural resource in your city, town, county, or region of the state. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize the solution*. Emphasize basing the plan on scientific principles. Examples of natural resources could include water, air, land, or organisms like trees or fish.

Each part of the above SEEd standard is identified in the following list:

Science and Engineering Practices (SEP) are bolded:

Design a solution in the form of a resource management plan

Crosscutting Concepts (CCC) are underlined:

to sustain (stability) a natural resource in your city, town, county,

Disciplinary Core Ideas (DCI) are added in the standard in regular/normal font:

Design a solution in the form of a resource management plan to sustain (stability) a natural resource in your city, town, county, or region of the state. *Define the problem, identify criteria and*

Engineering Expectations are italicized:

or region of the state. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize the solution*. Emphasize basing the plan on scientific

Emphasis Statements start with the word "Emphasize…":

the solution. Emphasize basing the plan on scientific principles. Examples of natural resources could include water, air,

Example Statements start with "Examples could include…":

Examples of natural resources could include water, air, land, or organisms like trees or fish.

Goal of the SEEd Standards

The Utah SEEd Standards is a research-grounded document aimed at providing accurate and appropriate guidance for educators and stakeholders. But above all else, the goal of this document is to provide students with the education they deserve, honoring their abilities, their potential, and their right to utilize scientific thought and skills for themselves and the world that they will build.

[1] National Research Council. 2012. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165. This consensus research document and its chapters are referred to throughout this document as a research basis for much of Utah's SEEd standards.

[2] Some Utah High School Supplemental SEEd Standards are based on the *Science Georgia Standards of Excellence* (Georgia Department of Education. 2016–2019. Science Georgia Standards of Excellence. Atlanta, GA. https://www.georgiastandards.org/Georgia-Standards/Pages/Science.aspx

ASTRONOMY

INTRODUCTION

The Astronomy High School Supplemental SEEd Standards explore the patterns, forces, relationships, and systems of matter and energy found in the Universe. Students develop models and investigate patterns observed on Earth and in the night sky of phenomena that affect life on Earth. Students ask questions and model objects in our solar system and design solutions to determine where and how humans could colonize off of our planet someday. Students build models and construct arguments for the life and death of stars predicting the final stage of stars based on their mass. Students develop models and explain the formation and characteristics of the Universe.

Strand ASTR.1: PATTERNS OBSERVED ON EARTH AND IN THE NIGHT SKY AFFECT LIFE ON EARTH AND SPACE EXPLORATION

The study of astronomy started as curious people observed and tried to explain phenomena observed on Earth by looking up at the sky. Models help to investigate and explain these phenomena using evidence for our current understanding. Space Exploration helps us better understand our planet and cause leaps in technology, culture, knowledge, and inspiration.

- **Standard ASTR.1.1** **Develop and use models** to evaluate the relationship between the relative positions of the Earth, Sun, and Moon and the phenomena caused by the relationship as observed from Earth. Emphasize how the location of the Earth, Sun, and Moon cause the phenomena. Examples of observable phenomena may include the day/night cycle, seasons, equinoxes and solstices, moon phases, eclipses, or tides.

- **Standard ASTR.1.2** **Plan and carry out an investigation** using the celestial sphere to explain how latitude and time of year affect the visibility of constellations, planets, and other celestial objects.

- **Standard ASTR.1.3** **Obtain, evaluate, and communicate information** about how patterns in ancient structures, instruments, philosophies, and civilizations influenced the study of astronomy. Examples of philosophies could include astronomical models (e.g., geocentric, heliocentric), Aristotelian physics, or Ptolemaic models with epicycles.

- **Standard ASTR.1.4** **Plan and carry out an investigation** to analyze patterns in telescopic data of various electromagnetic spectra to explain astronomical phenomena. Emphasize evaluating the uses and advantages of data to explain phenomena. Examples of data of various electromagnetic spectra could include absorption, redshift/blueshift, emission spectra, or blackbody curves.

- **Standard ASTR.1.5** **Construct an argument** based on evidence for the significance of historical and future space exploration as they relate to affecting leaps in technology, cultural cooperation, knowledge, and inspiration. Emphasize that historical space exploration began with Sputnik and continues to the present day.

Strand ASTR.2: STRUCTURES IN THE SOLAR SYSTEM AND THEIR FORMATION

Earth is one part of a larger solar system and objects within the solar system can be compared and classified. The objects and motions in the solar system provide evidence for the formation of the solar system. The solar system shares common forces, energy, and matter that can explain its characteristics and motion. Advances in technology make space travel and colonization possible if risks and constraints can be evaluated and overcome.

■ **Standard ASTR.2.1** **Ask questions** to **investigate** and communicate the structure and properties of objects in our solar system and the zones they inhabit. Emphasize grouping the objects found in the solar system into different categories based on their major properties. Examples of objects in the solar system could include planets, dwarf planets, major moons, asteroids, or comets. Examples of zones could include asteroid belt, Kuiper belt, or the Oort cloud.

■ **Standard ASTR.2.2** **Develop and use models**, based on evidence, to explain the formation of the solar system and the different proportions of matter and energy within regions of the system. Emphasize the cause of observed patterns of matter distribution in the solar system. Examples of matter distribution could include low amounts of ice found inside the frost line or the location of gas planets.

■ **Standard ASTR.2.3** **Use computational thinking** to model gravitational force at varying scale and proportion that explain motion and interaction of objects in the solar system. Emphasize that these forces are also at play throughout the universe. Examples of models could be conceptual, comparing force and motion of different objects in space, and do not require that students solve for the force of gravity acting on an object.

■ **Standard ASTR.2.4** **Design a solution** (plan) for a functioning human colony on an object in the solar system other than Earth. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize the solution*. Emphasize analyzing which planet/world of the solar system would have the best chance for a successful colony based on specific criteria. Examples of planets/worlds of the solar system could include Mars or moons of the Jovian planets. Examples of specific criteria could include distance from Earth, available energy sources, amounts of water or solvent, protection from solar radiation, or amount of resources/building materials.

Strand ASTR.3: STABILITY AND CHANGE IN THE LIFE OF STARS

Stars are born and die over a period of time in a process called stellar evolution. During a star's existence they may change in elemental composition, density, luminosity, temperature, and other ways. These changes can both be recognized and predicted.

- **Standard ASTR.3.1** **Develop and use models** to explain stability and change during the process of stellar evolution from birth to death of a star. Emphasize the causes for the changes during stellar evolution and the evidence that supports current understanding.
- **Standard ASTR.3.2** **Construct an argument** based on evidence from the Hertzsprung-Russell diagram to investigate properties (structure) of stars. Examples of properties of stars could include density, luminosity, temperature, rates of fusion, absolute magnitude, or spectral class.
- **Standard ASTR.3.3** **Ask questions** to evaluate evidence that predicts the stability and change of a star during its lifespan and its final stage of stellar evolution based on mass. Emphasize stellar remnants and events such as white dwarfs, neutron stars, pulsars, black holes, and supernovae.

Strand ASTR.4: MATTER AND ENERGY IN GALAXIES AND THE UNIVERSE

All matter and energy in the universe originate from a single event called the Big Bang. Since that time, matter in the form of different elements was formed through many processes, including the birth and death of stars. Dark matter and energy exist in the universe and affect its evolution. Galaxies also form and change through galactic evolution.

- **Standard ASTR.4.1** **Construct an argument** from evidence to explain the patterns that describe the formation of the universe. Emphasize the scientific theory of the Big Bang and evidence that supports it. Examples of evidence for the Big Bang could include the cosmological principle, cosmic microwave background radiation, Hubble's Law, observed galactic redshift, and time-space expansion.
- **Standard ASTR.4.2** **Use models** to describe the conditions of the early universe that led the formation and evolution of matter including the birth of the first stars and galaxies.
- **Standard ASTR.4.3** **Construct an explanation** using evidence to support the existence of dark matter and dark energy. Emphasize indirect evidence to support their existence.
- **Standard ASTR.4.4** **Develop and use models** to relate the cause for how galactic evolution occurs. Emphasize the processes of mergers and collisions.

BOTANY

INTRODUCTION

The Botany High School Supplemental SEEd Standards explore the patterns, processes, structures, functions, and relationships of plants on Earth. Students investigate and explain the major structures, functions, and processes plants use to survive and respond to their environment. Students construct explanations and arguments to classify plants into major plant taxa and determine their relationships, adaptations, and evolution. Students investigate and analyze data to explain how plants interact with and depend upon their environment for survival. Students investigate and explain the many ways that humans use and depend on plants.

Strand BOTN.1: STRUCTURES, FUNCTIONS, AND PROCESSES IN PLANTS

Plants have many different specialized structures (cells, tissues, and organs) that function to help them survive in their environment. These structures carry out specific life processes in plants. Plants have the ability to sense and respond to external stimuli in their environment.

- **Standard BOTN.1.1** **Ask questions** to **investigate** and provide explanations about basic plant structures and their related functions. Emphasize structures at the cellular, tissue, and organ levels. Examples of plant structures could include roots, root hairs, stem, phloem, xylem, cambium, leaf, stoma, flower, ovary, petal, stamen, or pistil.
- **Standard BOTN.1.2** **Construct an explanation** supported by evidence relating plant structures to plant processes. Examples of processes could include photosynthesis, respiration, transport, growth, reproduction, or seed dispersal.
- **Standard BOTN.1.3** **Develop and use models** to explain the cause for how plants sense and respond to external stimuli in their environment. Examples of external stimuli could include light, water, or soil changes.

Strand BOTN.2: PLANT EVOLUTION AND TAXONOMY

Plants can be compared taxonomically by comparing their structures, genes, and chemical processes. Plants are organized into taxonomic groups. Methods used to classify plants have changed over time with advancements in technology. The fossil record and other evidence show major changes in plants through geologic time. Plants coevolve with animals and other plants that have shared a symbiotic relationship for millions of years.

- **Standard BOTN.2.1** **Construct an explanation** based on evidence to compare patterns observed in structures, functions, and processes of different kinds of plants. Emphasize comparisons of nonvascular to vascular plants and seedless to seed plants.
- **Standard BOTN.2.2** **Construct an argument** based on evidence to classify plants into major plant divisions by observing patterns in physical or chemical characteristics. Emphasize traditional methods and emerging technologies used to identify and classify plants. Examples of technologies could be a dichotomous key, field guide, or molecular analysis (genes or chemicals).
- **Standard BOTN.2.3** **Develop and use models** to explain the origin of changes in major plant structures and organs through geologic time in response to environmental changes. Examples of changes in major plant structures could include development of vascular tissues or changing from spores to seeds).
- **Standard BOTN.2.4** **Construct an explanation** about the coevolution (change) of plant structures with animals and other plants. Examples of coevolution of plants could be due to pollination, nitrogen fixation, competition, and defenses from predators/parasites.

Strand BOTN.3: PLANTS AND THEIR ENVIRONMENT

Plants require matter and energy for survival. Plants affect their environment by providing diverse habitats for other organisms. Plant adaptations help them to survive changes that occur regularly in their environments. Changes in nutrient cycles in an environment may affect plant populations. States, counties, and communities create management plans to control invasive plant species and conserve native plants species.

- **Standard BOTN.3.1** **Plan and carry out an investigation** to explain how plants depend upon their environment to obtain the matter and energy necessary for survival. Examples of matter and energy in their environment could include soil, air, weather, other plants, or animals.

- **Standard BOTN.3.2** **Develop a model** to explain how plants affect their environment by providing diverse habitats for other organisms. Examples of other organisms that depend on plants could include birds, insects, or other wildlife.

- **Standard BOTN.3.3** **Construct an argument based on evidence** to predict which plant adaptations have led to (caused) increased survival rates in different stressful environments. Examples of stressful environments include changes in water, salinity, or temperature extremes.

- **Standard BOTN.3.4** **Analyze and interpret data** from investigations or models to describe how changes and disruptions in major nutrient cycles might affect plants. Examples of nutrient cycles could include carbon, oxygen, nitrogen, or phosphorus.

- **Standard BOTN.3.5** **Evaluate** current plans to manage the control of an invasive plant species in Utah or to manage the conservation of a native plant species in Utah focusing on the population's proportion and quantity. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine if the plan is an optimal solution.* Emphasize the impact that the plant species has on its environment.

Strand BOTN.4: HUMAN AND PLANT INTERACTIONS

Humans rely on plants for many different purposes. Investigations and data analysis can help us understand effective techniques for growing plants and improving fruit production. Plant pests and diseases affect plant crops and may have effects on humans and society. Genetically Modified plants may provide solutions to the effects of pest and disease and may also be a solution to food shortages, however, may also come with risks.

- **Standard BOTN.4.1** **Construct an explanation** for how plants and their structures are used in different societies. Examples of the use of plants could include agriculture, horticulture, industry, medicine, or biotechnology.

- **Standard BOTN.4.2** **Plan and carry out investigations** to determine effective techniques that cause improved plant growth and/or fruit production. Examples of testable variables could include soil type, nutrient/fertilizer, watering, spacing, or timing.

- **Standard BOTN.4.3** **Analyze and interpret data** to determine how plants are affected by insect pests, competing weeds, and diseases. Emphasize how plant pests and diseases in major plant crops affect humans, animals, and the economy and solutions to controlling them.

- **Standard BOTN.4.4** **Construct an argument based on evidence** for or against the use and effects of genetically modified plants. Emphasize comparing the benefits and risks for genetic modification. Examples of genetic modification could be through cross pollination and modern biotechnology.

ENVIRONMENTAL SCIENCE

Introduction

The Environmental Science High School Supplemental SEEd Standards explore the energy and material resources found on Earth and how these resources are obtained, used, managed, and conserved to support sustainable societies and ecosystems. Students model and analyze data to explain the organizations, factors, cycles, and changes that determine dynamic ecosystems. Students construct arguments for the risks and benefits of using renewable and nonrenewable energy sources and design energy management plans to identify sustainable energy solutions. Students construct explanations for how humans obtain and use natural resources; why resources can be abundant, scarce, and/or scattered around the world; and design a resource management plan to identify sustainable methods of obtaining and using resources. Students create arguments and explanations for how human use of natural and energy resources have an effect on the environment and what can be done to reduce or reverse human impacts on environments.

Strand ENVS.1: ECOLOGICAL SYSTEMS

Ecological systems have multiple levels of biological organization. Abiotic factors affect ecosystems and populations. Energy is transferred in ecosystems and predictable ways. Matter is cycled through environmental processes and necessary for ecosystem sustainability. Changes in ecosystems occur due to ecological succession. Biodiversity is critical for ecosystem resilience.

- **Standard ENVS.1.1** **Develop and use a model** to compare and analyze the levels of biological organization within living systems. Examples of levels of biological organization could include organisms, populations, communities, ecosystems, or biospheres.

- **Standard ENVS.1.2** **Ask questions** to **collect and analyze data** for how abiotic factors affect ecosystems and population adaptations. Examples of abiotic factors could include precipitation, temperature, elevation, or soil composition.

- **Standard ENVS.1.3** **Develop and use models** based on Laws of Thermodynamics to predict how energy transfers in ecosystems. Examples of energy transfer could be explained in terms of food chains, food webs, trophic levels, or carrying capacity.

- **Standard ENVS.1.4** **Analyze and interpret data** to construct an argument of the necessity of biogeochemical (matter) cycles to support sustainable ecosystems. Examples of biogeochemical cycles could include, hydrologic, nitrogen, phosphorus, oxygen, or carbon.

- **Standard ENVS.1.5** **Construct an argument from evidence** to predict changes in biomass, biodiversity, and complexity within ecosystems. Emphasize changes in terms of ecological succession over periods of time.

- **Standard ENVS.1.6** **Construct an argument from evidence** to support a claim about the value of biodiversity in ecosystem resilience (stability). Emphasize the value of biodiversity in ecosystem resilience. Examples of key factors in ecosystem resilience could include keystone, invasive, native, endemic, indicator, and endangered species.

Strand ENVS.2: AVAILABILITY AND USE OF NATURAL ENERGY

Energy sources are necessary for human society. Sources of energy can either be renewable or nonrenewable and have varying levels of quantity and proportion. Energy sources originate and are consumed differently. Energy plans provide a way to measure and calculate need and energy consumption in a sustainable way.

- **Standard ENVS.2.1** **Construct an argument** based on evidence about the risks and benefits caused by using renewable and nonrenewable energy sources. Examples of risks and benefits could include environmental, social, or economic factors.

- **Standard ENVS.2.2** **Analyze and interpret data** to communicate information on the origins, quantity/proportion, and consumption of renewable and nonrenewable energy sources. Examples of renewable energy sources could include wind, solar, geothermal, biofuel, or tidal. Examples of non-renewable energy sources could include fossil fuels and nuclear energy.

- **Standard ENVS.2.3** **Design a solution** in the form of a sustainable energy plan for your city, town, county or region of the state. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize the solution.* Emphasize basing the plan on scientific principles and on the sustainability potential of renewable and nonrenewable energy resources

Strand ENVS.3: AVAILABILITY, USE, AND MANAGEMENT OF NATURAL RESOURCES

Natural resources are necessary for human society. How humans obtain and use resources have an impact on their quality/quantity of the resource and their surrounding environment. Resource location, quantity, and proportion may be dependent on environmental factors. Governments and organizations manage the use and effect of natural resources. Resource management plans provide a way to measure and sustain resources for long-term use and effects.

- **Standard ENVS.3.1** **Construct an argument based on evidence** for the effects humans have by obtaining and using natural resources. Emphasize the uses and importance of resources and potential impacts of obtaining them. Examples of human activities to obtain resources could include agriculture, ranching, mining, forestry, fishing, water use, or desalination.
- **Standard ENVS.3.2** **Obtain, evaluate, and communication information** to explain how the location, quantity, and proportion of natural resources may be dependent on multiple environmental factors. Examples of environmental factors course include climate, geologic history, or soil composition.
- **Standard ENVS.3.3** **Construct an explanation** for why governments and organizations manage the use and effect of using natural resources. Emphasize how government and legislation affect management and sustainability plans. Examples of effects of management plans could include sustaining natural populations, market value of goods, or potential environmental impacts.
- **Standard ENVS.3.4** **Design a solution** in the form of a resource management plan to sustain (stability) a natural resource in your city, town, county, or region of the state. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize the solution.* Emphasize basing the plan on scientific principles. Examples of natural resources could include water, air, land, or organisms like trees or fish.

Strand ENVS.4: SUSTAINABILITY AND HUMAN IMPACTS BOTH LOCAL AND GLOBAL

Human use of natural and energy resources has an effect on the environment. Population growth generally requires an increased use of these resources and has an increased effect. Humans have found solutions to some of these effects. There is a relationship between the quality of life and human impact on the environment. Some human impacts can have lasting effects on environments around the world and adjusting practices can reduce and reverse the effects. Global climate change is occurring and has an effect on both human populations and environments. Sustainability plans help individuals, cities, or regions reduce their impact on environments.

■ **Standard ENVS.4.1** **Construct an argument** to evaluate how human population growth affects natural resources and the potential solutions to these effects. Examples of resources affected by human population growth could include food demand, food supply, waste disposal, or land use. Examples of potential solutions could include genetically modified organisms, hydroponics, wastewater treatment, or improved recycling systems.

■ **Standard ENVS.4.2** **Construct explanations** about the relationship between the quality of life and human impact (effect) on the environment in terms of population growth, education, and gross national product. Emphasize the role of sustainable practices to support both humans and nature.

■ **Standard ENVS.4.3** **Obtain, evaluate, and communicate information** for how humans cause an impact on the environment and how individuals, state and local management plans, and government legislation have identified and adjusted practice to reduce and/or reverse these impacts. Emphasize the process and time necessary to pass Examples of impact could include water and air pollution, climate change, ozone depletion, deforestation, ocean acidification, or urbanization. Examples of adjusted practice could include the reduction of fossil fuel use, criminalization of dumping waste, or outlawing the use of chlorofluorocarbons.

■ **Standard ENVS.4.4** **Analyze and interpret data** to construct an explanation based on evidence for the causes and impacts of global climate change on human populations and environments. Examples of evidence could include ice cores, ocean acidification, glacier retreat, atmospheric CO_2 levels, or air and ocean temperature.

■ **Standard ENVS.4.5** **Design** and defend **a solution** in the form of a sustainability plan to reduce individual, city, or regional contribution (causes) to environmental impacts. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize the solution.* Emphasize how market forces and societal demands influence personal choices.

GENETICS

Introduction

The Genetics High School Supplemental SEEd standards explore the structures, functions, patterns, and processes that cause and effect heredity and genetic expression in living things. Students develop and use models to understand the structure of DNA and how mutations occur. Students plan and carry out investigations to identify genetic patterns in inherited traits and characteristics. Students obtain, evaluate, and communicate information about bioengineering and its impact on humanity.

Strand GENE.1: STRUCTURE AND FUNCTION OF MOLECULAR GENETICS

The structure of DNA enables the process of both protein synthesis and inheritance. Genes located on chromosomes encode instructions for proteins that result in the characteristics of organisms. Mitosis and meiosis affect the transmission of alleles from one generation to the next. There are many causes of mutations which have a variety of effects.

- **Standard GENE.1.1** **Develop and use a model** illustrating how the structure of DNA enables the process of both protein synthesis and inheritance.
- **Standard GENE.1.2** **Analyze and interpret data** to determine how changes to genes may cause an organism's characteristics to vary. Emphasize that genes located on chromosomes encode instructions for proteins that can result in the characteristic(s) of organisms.
- **Standard GENE.1.3** **Obtain, evaluate, and communicate information** about the patterns in the processes of cell divisions and how they affect the transmission of alleles from one generation to the next. Emphasize the similarities and differences in the processes of both mitosis and meiosis.
- **Standard GENE.1.4** **Ask questions** to **construct an explanation** about the causes and effects of mutations on an organisms' traits.

Strand GENE.2: PATTERNS OF CHROMOSOMAL GENETICS

Mendelian genetics account for the predictability and variability of genetic patterns in all organisms. Sex-linked inheritance leads to changes in the probability that a phenotype will be expressed based on sex. Multifactorial traits are attributable to both the environment and genes. Random genetic variations within a population and natural selection pressures both impact evolutionary change of that population.

- **Standard GENE.2.1** **Plan and carry out an investigation** to analyze the predictability and variability of genetic patterns in diploid organisms as described by mendelian genetics.
- **Standard GENE.2.2** **Use mathematics and computational thinking** to explain how that sex-linked inheritance leads to changes in the probability that a phenotype will be expressed based in certain sexes. Emphasize the genes and traits that can be inherited on sex chromosomes.
- **Standard GENE.2.3** **Engage in argument from evidence** about how multifactorial traits are a result of interactions between external (environmental) systems and internal systems of the organism.
- **Standard GENE.2.4** **Analyze and interpret data** to investigate how the scale, proportion, and quantity of random occurrences affect the genetic makeup of a population. Emphasize that random genetic variation within a population and natural selection pressures both impact evolutionary change.

Strand GENE.3: CAUSES AND EFFECTS OF BIOENGINEERING

Technology has been applied in numerous fields including agriculture, medicine, and industry. The completion of the Human Genome project has led to advances in the area of genomics. Biotechnology has been used to identify and modify genes which may be used for a variety of valid outcomes, but may also raise ethical issues concerning research and application that have had an effect on humankind.

- **Standard GENE.3.1** **Engage in argument from evidence** about how the structure and function of biotechnology is used to modify genes in a way that can affect humankind including application potential ethical concerns. Emphasize technologies' affect on agriculture, medicine, and industry. Examples of technology could include GMOs, cloning, diagnosing and treating genetic disorders, and CRISPR.

- **Standard GENE.3.2** **Ask questions** to **obtain, evaluate, and communicate information** about the human genome project and its effects in the area of genomics.

- **Standard GENE.3.3** **Analyze and interpret data** to evaluate different **designed solutions** where biotechnology uses matter and energy to identify and/or modify the structure and function of genes in order to solve a problem. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions,* consider potential ethical concerns, *and determine an optimal solution.*

GEOLOGY

Introduction

The Geology High School Supplemental SEEd standards explore matter and energy that form the rocks, minerals, and formations found in Earth. Students carry out investigations to identify and classify different minerals and rocks. Students ask questions to evaluate what can be learned from the geologic record. Students develop and use models of the Earth and its interior. Students obtain, evaluate, and communicate information to understand Earth's surface processes. Students analyze and interpret data about the interaction between humans and the Earth in an attempt to mitigate geologic hazards, minimize property damage, and preserve lives.

Strand GEOL.1: PATTERNS OF MINERALS AND ROCKS

Minerals and rocks are classified by their properties, characteristics, and how they form and change.

- **Standard GEOL.1.1** **Plan and carry out investigations** to explore the structure and properties of different minerals to classify them based on their characteristics.
- **Standard GEOL.1.2** **Analyze and interpret data** to identify the patterns that are present in different rocks to classify them based on their properties, characteristics, and how they were formed.
- **Standard GEOL.1.3** **Develop a model** which demonstrates how matter is cycled and how energy flows throughout the rock cycle. Emphasize the processes that form plutonic (intrusive) and volcanic (extrusive) igneous rocks, the processes that form sedimentary rocks (weathering, erosion, deposition, burial, dissolution, precipitation, compaction, and cementation), and the conditions of metamorphism including how the starting (parent/protolith) rock compositions determine the metamorphic rock type.

Strand GEOL.2: STABILITY AND CHANGE OF THE GEOLOGY RECORD

Steno's laws of stratigraphy describe the patterns in which rock layers are deposited. Analyzing Earth's rock layers reveal the geologic history of an area. Geologic timelines can be established using both quantitative and qualitative measurements. Fossil information found in the rock layers can reveal evidence of change in the populations and environments of a region over time.

- **Standard GEOL.2.1** **Ask questions** to **analyze and interpret data** about the stability of rock layers and how they can change according to Steno's laws of stratigraphy
- **Standard GEOL.2.2** **Engage in argument from evidence** applying stratigraphic principles to interpret the relative geologic history of an area(system).
- **Standard GEOL.2.3** **Use mathematics and computational thinking** to determine the age of geologic layers using different measurements of scale, proportion, and quantity. Emphasize relative and absolute dating principles as well as the fossil record.
- **Standard GEOL.2.4** **Obtain, evaluate, and communicate information** about the causes of fossilization and how the fossil record provides evidence of change in environments and life over time.

Strand GEOL.3: MATTER AND ENERGY OF EARTH'S INTERIOR AND PLATE TECTONICS

The physical and chemical layers of Earth's interior have different structure and properties. These layers provide the mechanisms which cause plate tectonics and different observable surface features.

- **Standard GEOL.3.1** **Develop and use a model** that explains the structure of Earth's interior. Emphasize both the physical (lithosphere, asthenosphere, mesosphere, outer core, inner core) and chemical (crust, mantle, core) layers.
- **Standard GEOL.3.2** **Engage in argument from evidence** about the patterns and claims that explain the theory of plate tectonics. Examples of evidence could include earthquake patterns, volcanic arcs, benioff zones, seafloor age and magnetic striping, and topographic and bathymetric features.
- **Standard GEOL.3.3** **Construct an explanation** how the matter and energy in Earth's interior causes different stresses on the surface, affecting and forming different visible features. Examples of these features could include fault types (normal, reverse, sinistral, dextral) and fold types (anticlines, synclines).

Strand GEOL.4: CAUSES AND EFFECTS OF SURFACE PROCESSES

Climate and weather impact how soil and sediments form. Environment systems have different landforms which are formed by a variety of mechanisms. Surface water and groundwater are major agents of change within these geologic systems.

- **Standard GEOL.4.1** **Ask questions** to **analyze data** about the effects of regional climate on weathering processes and soil/sediment formation.
- **Standard GEOL.4.2** **Obtain, evaluate, and communicate information** to characterize the formation of erosional and depositional landforms in different environment systems. Emphasize information from geologic maps, topographic maps, cross-sectional maps, and remote sensing data. Examples of environment systems could include desert, glacial, coastal, and fluvial environments.
- **Standard GEOL.4.3** **Plan and carry out an investigation** to collect and analyze data on how surface water and groundwater act as major agents of change in geologic systems. Emphasize surface reservoirs, groundwater reservoirs, and fluvial systems. Examples of processes of change could include infiltration, runoff, evaporation, precipitation, cementation, karst, and mass wasting..

Strand GEOL.5: SYSTEM INTERACTIONS BETWEEN HUMANS AND THE EARTH

Humanity relies on the resources contained within Earth. The extraction of resources from Earth impacts the geologic systems. Technology can be designed and used to mitigate geologic hazards, minimize property damage, and preserve life.

- **Standard GEOL.5.1** **Ask questions** to **obtain, evaluate, and communicate information** on the origin, distribution, economic importance, extraction, and use of resources in Earth's geologic system. Emphasize resources found in Utah. Examples of resources could be metals, ores, minerals, water, and energy resources.

- **Standard GEOL.5.2** Evaluate **design solutions** which have a structure and function to mitigate geologic hazards, minimize property damage, and preserve life. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine an optimal solution.*

HUMAN ANATOMY

Introduction

The Human Anatomy High School Supplemental SEEd standards explore the structure, function, and interactions of tissues, organs, and organ systems found in humans. Students develop and use models to illustrate anatomical structures and regions of the human body. Students construct explanations of how the integumentary, skeletal and muscular systems make support, protection, and movement possible. Students analyze and interpret data to understand how the endocrine and nervous systems make information processing possible. Students ask questions about the relationships between the cardiovascular, respiratory, digestive, and urinary systems. Students obtain, evaluate, and communicate information about the male and female reproductive systems that make conception, development, and birth of human life possible.

Strand HUMA.1: ANATOMICAL STRUCTURES OF THE HUMAN BODY

The anatomical structures of the human body have a specific orientation and location. The size of the body's structures fulfill different functions.

- **Standard HUMA.1.1** **Develop and use models** to demonstrate the orientation of anatomical structures and regions of the human body. Emphasize how size, orientation, and location within the human body supports the function of the anatomical structures.

- **Standard HUMA.1.2** **Obtain, evaluate, and communicate information** about how the scale, proportion, and quantity of different body structures affects their functions within the human body. Emphasize the roles of cells, tissues, organs, and organ systems.

Strand HUMA.2: INTEGUMENTARY, SKELETAL, AND MUSCULAR SYSTEMS

The integumentary system plays an important role in protection, eliminating waste products, and regulating body temperature. The skeletal system provides the body with movement, protection, and support. The muscular system also provides the body with movement and support. The integumentary, skeletal, and muscular systems work together to provide the body with support, protection, and movement.

- **Standard HUMA.2.1** **Construct an explanation** about the relationship between the structures of the integumentary system and their role in protection, eliminating waste products, and regulating body temperature.
- **Standard HUMA.2.2** **Develop and use models** to relate the structure of the skeletal system to its functional role in movement, protection, and support.
- **Standard HUMA.2.3** **Plan and carry out an investigation** to determine the cause and effect relationship between structures of the muscular system and their role in movement and support.
- **Standard HUMA.2.4** **Engage in argument from evidence** about how the integumentary, skeletal, and muscular systems make support, protection, and movement possible. Emphasize the homeostatic mechanisms, as well as the effects of and responses to nutrition, aging, diseases, and disorders.

Strand HUMA.3: ENDOCRINE AND NERVOUS SYSTEMS

The nervous system is the body's means of information processing. The endocrine system regulates the physical and chemical processes of the body. The endocrine and nervous systems work together to help the body process information.

- **Standard HUMA.3.1** **Plan and carry out an investigation** to determine how the structures of the nervous system support the function of information processing (detection, interpretation, and response) within the body.
- **Standard HUMA.3.2** **Analyze and interpret data** to explain how the hormones of the endocrine system regulate physical and chemical processes to maintain a stable internal environment, support general health, and promote growth and development throughout the lifespan. Emphasize both positive and negative feedback mechanisms. Examples of feedback mechanisms could be heart rate, blood sugar, childbirth, temperature, and growth.
- **Standard HUMA.3.3** **Construct an explanation** about how the cause and effect relationship of the endocrine and nervous systems makes information processing (detection, interpretation and response) possible. Emphasize homeostatic mechanisms and their effects and responses to nutrition, aging, diseases, and disorders.

Strand HUMA.4: CARDIOVASCULAR, RESPIRATORY, DIGESTIVE, AND URINARY SYSTEMS

The cardiovascular and respiratory system help the body obtain oxygen, transport nutrients, and remove waste. The digestive and urinary systems help the body obtain nutrients and eliminate waste. The cardiovascular, respiratory, urinary, and digestive systems are interdependent yet responsive to each other. Measurements of cardiovascular, respiratory, digestive, and urinary systems processes can indicate the relative health of the body.

- **Standard HUMA.4.1** **Analyze and interpret data** to identify patterns that explain how the cardiovascular and respiratory systems obtain oxygen, transport nutrients, and remove waste.

- **Standard HUMA.4.2** **Obtain, evaluate, and communicate information** about the relationship between the structure and function of the digestive and urinary systems as they utilize matter to derive energy and eliminate waste.

- **Standard HUMA.4.3** **Ask questions** to **construct an explanation** about the interdependence of the cardiovascular, respiratory, urinary, and digestive systems. Emphasize homeostatic mechanisms, as well as the effects of and responses to nutrition, aging, diseases, and disorders.

- **Standard HUMA.4.4** **Use mathematics and computational thinking** to **design** a device which measures the exchange of matter and energy used by the cardiovascular, respiratory, digestive, and urinary systems to determine health of those systems and to prevent potential health issues. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution.* Examples of measurements could include caloric input to the digestive system, respiratory gas output, respiratory rates, respiratory volumes, digestive rates, heat lost by urine output, blood pressure, and heart rate.

Strand HUMA.5: REPRODUCTIVE SYSTEM'S ROLE IN THE GROWTH AND DEVELOPMENT OF HUMANS

The reproductive system produces the structures needed to produce egg and sperm, fertilization, and the development of offspring. Human embryos progress through different stages of growth and development supported by the reproductive system

- **Standard HUMA.5.1** **Obtain, evaluate, and communicate information** about how the structures of the male and female reproductive system provide a stable yet changing environment to allow for the production of egg and sperm, fertilization, implantation, and the development of human fetus. Emphasize the role of hormones in the male and female reproductive process.
- **Standard HUMA.5.2** **Develop and use models** to describe the stability and change in the stages of human embryology and gestation, including fertilization and embryo and embryo and fetal development. Emphasize the embryological changes through the different stages of development.
- **Standard HUMA.5.3** **Ask questions** about how the reproductive system uses matter and energy to make growth and development possible. Emphasize homeostatic mechanisms, as well as the effects of and responses to nutrition, aging, diseases, and disorders.

MARINE SCIENCE

Introduction

The Marine Science High School Supplemental SEEd standards explore the interactions and processes that affect living things in the ocean. Students develop and use a model to describe the characteristics, properties and influences of the ocean and seawater. Students analyze and interpret data about marine life to classify them into different marine phyla and to determine their relationships within marine ecosystems. Students ask questions to obtain, evaluate, and communicate information about the interaction between humans and the ocean.

Strand MSCI.1: STRUCTURE AND FUNCTION OF THE OCEAN

Plate tectonics allowed the oceans to form with different marine zones. The unique properties of seawater influence and effect characteristics of the marine zones within the water column. Water surface phenomena influence the shoreline and affect marine life.

- **Standard MSCI.1.1** **Develop and use models** which use scale, proportion, and quantity to describe the Earth's oceans and the different marine zones.
- **Standard MSCI.1.2** **Plan and carry out an investigation** to explain the unique properties, structure, and function of seawater when compared to freshwater. Emphasize the properties of temperature, polarity, solubility, salinity, density and how they change in the water column.
- **Standard MSCI.1.3** **Engage in argument based on evidence** for how the patterns of sea water, tides, currents, waves, and weather affect the shoreline and influence the evolution, adaptations, and distributions of marine populations.

Strand MSCI.2: MARINE ECOSYSTEMS

Scientific theories state that the earliest life on Earth originated from the ocean. Marine life in the ocean relies on chemosynthesis and photosynthesis to produce energy. A wide variety of marine life now exists in a variety of marine ecosystems which can be classified based on their characteristics. Energy flows and matter cycles within and between different marine ecosystems.

- **Standard MSCI.2.1** **Construct an explanation** of how populations of organisms evolved (changed) over time as ocean ecosystems changed. Emphasize that the earliest life on Earth originated in the ocean.
- **Standard MSCI.2.2** **Ask Questions** to **analyze and interpret data** for how matter and energy is used during photosynthesis and chemosynthesis in oceanic ecosystems. Emphasize the ocean zones in which photosynthesis and chemosynthesis are the primary mode of production in ocean organisms.
- **Standard MSCI.2.3** **Analyze and interpret data** about marine life from varying marine ecosystems to classify them into different marine phyla using structure and function, distinguishing characteristics, and adaptations.
- **Standard MSCI.2.4** **Develop and use models** to analyze the flow of energy and cycling of matter in marine ecosystems. Examples of models could include food webs, trophic levels, and carbon exchange.
- **Standard MSCI.2.5** **Obtain, evaluate, and communicate information** regarding the stability and change of relationships between biotic and abiotic factors in marine ecosystems. Examples of ecosystems could include estuaries, coral reefs, kelp forests, the open ocean, and the deep ocean.

Strand MSCI.3: SYSTEM INTERACTIONS BETWEEN HUMANS AND THE OCEAN

Interactions between humans and the ocean have occurred throughout history for a variety of reasons. Human activities may affect marine ecosystems. Climate change affects the ocean and marine ecosystems. Sustainability plans may affect changes to marine environmental systems.

- **Standard MSCI.3.1** **Ask questions** to **obtain, evaluate, and communicate information** about the patterns that exist in the interactions between humans and the marine environment throughout history. Emphasize historical and modern motivations for oceanic exploration and research as well as the associated challenges and findings.

- **Standard MSCI.3.2** **Engage in argument based on evidence** about how human activities may affect marine ecosystems. Examples of human activities could include the extraction of resources, transportation, and recreation.

- **Standard MSCI.3.3** **Analyze and interpret data** to investigate the causes and effects of climate change on the ocean and marine ecosystems. Examples of data to investigate could be sea level rise, thermal expansion, ocean acidification, ocean temperature, biomagnification of pollutants, ocean deoxygenation, and eutrophication.

- **Standard MSCI.3.4** **Design a solution** in the form of a sustainability plan that impacts individual, city, or regional contributions (changes), including Utah, to marine environmental systems. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution.*

METEOROLOGY

Introduction

The Meteorology High School Supplemental SEEd standards explore the energy and matter of the atmosphere, the stability and change of these two factors, and how they form weather patterns. Students analyze and interpret data to determine the structure and function of the atmosphere. Students develop and use models to assist them in weather analysis and forecasting. Students analyze and interpret data to help them communicate the system interactions that occur between society and the climate.

Strand METR.1: STRUCTURE AND FUNCTION OF EARTH'S ATMOSPHERE

The atmosphere has different layers and composition which can be identified from its properties. Observable changes in solar radiation affect both the atmosphere and the surface of Earth.

- **Standard METR.1.1** **Construct an explanation** describing the properties and structure and function of the atmospheric layers. Emphasize the properties of temperature, density, chemical composition, pressure, humidity, and moisture.
- **Standard METR.1.2** **Develop a model** that explains observable seasonal variations (changes) in insolation. Emphasize the length of daylight hours, angle of midday sun, and Earth's axial tilt.
- **Standard METR.1.3** **Obtain, evaluate, and communicate** what happens to solar radiation (energy) as it moves through the atmosphere and interacts with Earth's surface (matter). Emphasize the role of the greenhouse effect on supporting life.
- **Standard METR.1.4** **Analyze and interpret data** to determine the cause and effect of changes in Earth's surface conditions. Examples of data to analyze could be humidity, density, temperature, dew point, wind direction, cloud types, and precipitation.
- **Standard METR.1.5** **Ask Questions** to **obtain, evaluate, and communicate information** about the scale, proportion, and quantity of different types of clouds and precipitation. Emphasize the formation process and their effects on Earth's surface.

Strand METR.2: DEVELOPING AND USING MODELS IN WEATHER ANALYSIS AND FORECASTING

Models can be used to represent different weather systems and how they interact with each other. These interactions can be used to predict future weather conditions and determine the potential for hazardous weather. Technology aids in both the analysis and protection against hazardous weather.

- **Standard METR.2.1** **Ask questions** to **analyze data** to compare the relationships between different weather systems. Emphasize air masses, source regions, weather fronts, pressure systems, and the changes associated with frontal passage. Examples could include air density, temperature, dew point, wind direction, cloud types, and precipitation.

- **Standard METR.2.2** **Develop and use a model** which displays different scales, proportions, and quantities of measurements and can be used to predict the weather. Emphasize using weather maps as models. Examples of measurements could include high- and low -pressure systems, isobars, wind barbs, and fronts.

- **Standard METR.2.3** **Plan and carry out an investigation** to identify patterns in how hazardous meteorological events are formed. Emphasize the formation of severe thunderstorms, hurricanes, tornadoes, floods, droughts, and winter storms.

- **Standard METR.2.4** **Obtain, evaluate, and communicate** the role of technology and public awareness systems on weather forecasting. Examples could include NOAA/NWS observation data network, instrumentation, satellites, radar, weather balloons, models, watch/warning criteria.

- **Standard METR.2.5** **Use mathematics and computational thinking** to **design** and evaluate a safety plan that protects (affects) against common weather events for a local geographic location. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution.*

Strand METR.3: SYSTEM INTERACTIONS BETWEEN SOCIETY, EARTH'S CLIMATES, AND WEATHER

Various climate systems are present across the world with a variety of characteristics and conditions. Weather, climate, and society interact and affect each other. Climate change is defined as any systematic change in the long-term statistics of climate elements (such as temperature, pressure, or winds) sustained over several decades or longer. Climate change can have a variety of causes and effects. Technology and regulation can aid in minimizing property damage, preserving life, and reducing the impacts of climate change.

- **Standard METR.3.1** **Analyze and interpret data** to construct explanations for various global climate systems. Emphasize climatic characteristics such as latitudinal variations in insolation, distribution of land and water, prevailing winds, average temperature and precipitation, atmospheric circulation, physical geography, altitude, and ocean currents.

- **Standard METR.3.2** **Engage in argument from evidence** to identify the patterns that exist in the relationships between weather, climate, and society. Examples could include hazardous weather, urban heat island, smog formation, air pollution, air quality, stratospheric ozone.

- **Standard METR.3.3** **Obtain, evaluate, and communicate information** about the potential individual and societal effects of changing weather patterns and climate conditions. Emphasize the effects on economic, social, health (physical and emotional), political, and ecological systems.

- **Standard METR.3.4** **Plan and carry out an investigation** to determine the natural and human caused factors that produce changes in global climate. Emphasize Milankovitch and ENSO cycles, role of greenhouse gases, and changes in physical geography.

- **Standard METR.3.5** Evaluate proposed **designed solutions** intended to minimize property damage and preserve life by reducing the impacts (effect) of climate change and hazardous weather. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine an optimal solution.*

WILDLIFE BIOLOGY

INTRODUCTION

The Wildlife Biology Science High School Supplemental SEEd Standards explore the factors, processes, relationships, and interactions of wildlife in nature. Students analyze data and construct explanations for the characteristics, behaviors, and interactions of abiotic and biotics factors that make up an ecosystem. Obtain and evaluate information and construct arguments to communicate how organisms are identified and how they, and their effects on their habitat, can be studied in the wild. Analyze data and use mathematical reasoning to determine the health of wildlife observing both quantitative and qualitative factors. Students create arguments and explanations for how human activities have an effect on wildlife and their habitat and design solutions to what can be done to reduce or reverse human impacts on wildlife populations and habitats.

Strand WILD.1: ECOLOGICAL PROCESSES AND ENVIRONMENTAL FACTORS

Ecological habitats are shaped by abiotic factors that determine the living organisms that live there. Energy is a limiting factor for population size and growth in an ecosystem. Behaviors and interaction between organisms also have a role in the dynamics of an ecosystem.

- **Standard WILD.1.1** **Analyze and interpret data** for how abiotic factors affect characteristics of ecosystems and the individual organisms living there. Examples of abiotic factors could include seasonal climate, latitude, elevation, or soil composition. Examples of effects of abiotic factors could include temperature regulation strategies in endothermic and exothermic animals or the effect of day/night lengths on antler growth.

- **Standard WILD.1.2** **Use computational thinking** to model and explain how the quantity of available energy is the limiting factor for population size and growth in an ecosystem. Emphasize how the laws of thermodynamics affect the amount of energy available in a trophic level and affect the ecosystem's carrying capacity. Examples of explanatory models could include an ecological energy pyramid or carrying capacity graphs.

- **Standard WILD.1.3** **Construct an explanation** for how behaviors of and interactions between organisms affect populations and population dynamics in an ecosystem. Examples of behaviors could include migration, food storage, or grazing. Examples of interactions could include symbiotic relationships, predator/prey relationships, competition, or decomposers. Examples of population dynamics could include population size, diversity, dispersal, birth/death rate, or survivorship.

Strand WILD.2: IDENTIFYING ORGANISMS AND THEIR FUNCTION IN THEIR ENVIRONMENT CLASSIFICATION

Organisms can be identified and studied based on their physical structure and characteristics using classification tools. Classification systems change as technologies and information about species improve. Organisms can have an impact on their environment and other organisms. Invasive species affect ecosystems in ways that can be predicted and measured.

- **Standard WILD.2.1** **Obtain, evaluate, and communicate information** about organisms by using classification tools to identify and study them based on physical structures and characteristics. Emphasize a focus on different kinds of organisms—plants, animals, fungi, and lichen. Examples of classification tools could include a field guide or dichotomous key.
- **Standard WILD.2.2** **Construct an argument from evidence** for why there are ongoing changes to classification schemes and systems. Emphasize the role of technology to provide added understanding of organisms by looking at their genetic and chemical characteristics.
- **Standard WILD.2.3** **Construct an explanation** for how organism characteristics and behaviors impact their environment (system). Examples of characteristics that impact the environment could include roots of plants affecting how stream or river flows or the presence of a keystone species can determine populations of other species. Examples of behaviors could include migration paths, pollination preferences, or burrow/tunnel creation.
- **Standard WILD.2.4** **Analyze and interpret data** to identify invasive species, describe how they are introduced, describe why they are successful in the environment, and predict/measure their effects on an ecosystem.

Strand WILD.3: DATA COLLECTION AND ANALYSIS OF WILDLIFE POPULATIONS

Understanding the quantitative and qualitative data for an environment or population is critical to understanding its health. There are techniques used to collect data for quantitative and qualitative characteristics of a population. Mathematical reasoning and statistical principles are used to estimate current population sizes based on a sample and to predict how a population may change based on environmental factors. Wildlife Biologists investigate how changes to an ecosystem may affect the ecosystems dynamics.

- **Standard WILD.3.1** **Obtain, evaluate, and communicate information** about techniques used to take population measurements that determine quantity and quality of populations. Emphasize an evaluation of both quantitative and qualitative characteristics of populations. Examples of qualitative measures could include analysis of leaf color, tree core samples, dentition examination, or scat evaluation.
- **Standard WILD.3.2** **Use mathematical reasoning** and statistical principles that use data to estimate current population sizes (scale and quantity) in an ecosystem based on a smaller sample size. Emphasize using grade-level mathematical and statistical principles.
- **Standard WILD.3.3** **Use mathematical reasoning** and statistical principles to model and predict how a population may change given data about current populations and environmental factors. Emphasize using grade-level mathematical and statistical principles.
- **Standard WILD.3.4** **Plan and carry out an investigation** to predict and measure how a single change to an ecosystem may affect the dynamics of the ecosystem.

Strand WILD.4: HUMAN IMPACT AND WILDLIFE MANAGEMENT

Human activities have an effect on ecological systems and wildlife. Humans have found some solutions to minimize or reduce the effects of their actions. Species go extinct for specific reasons and their extinction may have an impact on their environment. Humans identify and protect endangered species to limit the effects of this extinction. Ecological collapse can occur if significant changes to the environment occur. Wildlife management plans are created and executed to support a wildlife habitat and/or specific species.

- **Standard WILD.4.1** **Construct an argument based on evidence** for the impacts (effects) humans have on ecological systems and wildlife. Emphasize a historical context for how individuals, state and local management plans, and government have identified and adjusted practice to reduce and/or reverse these impacts. Also emphasize how the level of urban development in and around the ecosystem may make management plans more challenging compared to an area where urbanization is just starting. Examples of impacts could include water and air pollution, deforestation, poaching, ocean acidification, or urbanization.
- **Standard WILD.4.2** **Construct an explanation** for the effects that are caused when species go extinct and how endangered species are determined and protected.
- **Standard WILD.4.3** **Analyze and interpret data** to explain the causes and effects of ecological collapse. Emphasize investigating specific examples of this happening on Earth.
- **Standard WILD.4.4** **Obtain, evaluate, and communicate information** for the purpose, creation, execution, and effects of a wildlife management plan. Emphasize how wildlife management plans differ between states and countries and how they have changed over time. Examples of components in the wildlife management plan could include habitats, threats, species management/conservation, monitoring plans, and/or implementation approach.
- **Standard WILD.4.5** **Design a solution** in the form of a wildlife management, conservation, or restoration plan to support (effect) a specific habitat or a specific population. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize the solution.* Emphasize basing the plan on scientific principles.

ZOOLOGY

INTRODUCTION

The Zoology Science High School Supplemental SEEd Standards explore the patterns, processes, structures, functions, and relationships of animals on Earth. Students model and explain the major structures, functions, and processes animals use to survive in their environment. Students construct explanations and arguments to classify animals into major animal taxa and determine their relationships, adaptations, and evolution. Students will analyze data and build models to explain comparative zoology principles and how animal phyla increase in complexity from the phylum porifera to chordata. Students investigate and explain the many ways that humans use and depend on animals and how humans have an impact on animal populations. Students evaluate plans to control invasive animal species in Utah and/or conserve native Utah animal species.

Strand ZOOL.1: STRUCTURES, FUNCTIONS, AND PROCESSES IN ANIMALS

Animals share common life functions necessary for survival. They also have similar yet diverse structures that they use to fulfil these life functions. Some animals have a unique life cycle. Animals depend upon their environment for survival.

- **Standard ZOOL.1.1** **Obtain, evaluate, and communicate information** to explain the life functions shared by most animals. Emphasize that most animals depend on and perform these functions in different ways. Examples of life functions could include the need to feed, respire, circulate, excrete, move, respond, or reproduce.

- **Standard ZOOL.1.2** **Develop and use models** to explain the complexity and diversity of common animal structures (systems, organs, tissues, and cells) and their functions to fulfil life functions. Emphasize how different structures in different organisms perform similar functions.

- **Standard ZOOL.1.3** **Develop a model to explain** the patterns in various life cycles and embryological development differences in animals. Emphasize the potential reasons and benefits for these differences. Examples of life cycles could include polyp and medusa in cnidarians; different hosts and stages in the platyhelminths or nematode life cycle; arthropod metamorphosis; or chordates life cycles in fish and amphibians. Examples of embryological development differences could include oviparous, viviparous, ovoviviparous organisms.

- **Standard ZOOL.1.4** **Construct an explanation** for how animals depend upon their environment for survival in their habitat (system). Examples of necessities provided by their environment could include food, weather, or shelter.

Strand ZOOL.2: COMPARATIVE ZOOLOGY, EVOLUTION AND PHYLOGENY

Evolution by natural selection allows populations to adapt to environmental changes. Some animals have coevolved with plants or other animals. Animals are classified into major taxa and this classification can be used for phylogenetic context. Most animals show increased complexity in different ways when comparing them from phyla to phyla.

- **Standard ZOOL.2.1** **Construct an explanation** for how evolution allows populations to adapt to environmental changes. Emphasize the mechanisms that drive evolution in animal populations. Examples of evolution drivers could include adaptation, natural selection, convergence, and speciation.

- **Standard ZOOL.2.2** **Construct an argument from evidence** about the coevolution (change) of animals with plants and other animals. Examples of coevolution with plants could be due to pollination or seed dispersal. Examples of coevolution with other animals could be due to predator/prey relationships or symbiotic relationships.

- **Standard ZOOL.2.3** **Construct an argument based on evidence** to classify animals into major taxa by observing patterns in physical, behavioral, or molecular/genetic characteristics. Emphasize placing taxa into phylogenetic context using different technologies. Examples of technologies could be a dichotomous key, field guide, or molecular analysis (genes or chemicals).

- **Standard ZOOL.2.4** **Analyze and interpret data** to explain patterns in the increasing complexity in the morphology, biochemistry, and genetics of animals to compare taxa within and between phyla. Emphasize focusing the comparisons using the structures, functions, and processes identified in Strand 1 of these standards. Examples of phyla to compare could include Porifera, Cnidaria, Platyhelminthes, Nematoda, Annelida, Mollusca, Arthropoda, Echinodermata, and/or Chordata.

Strand ZOOL.3: HUMAN AND ANIMAL INTERACTIONS

Animal structures are used for different purposes by humans. Human activities may have an impact on natural habitats and populations of animals. Humans can also create management plans and legislation that can reduce or reverse the impacts humans have on animals in the wild. Management plans can be used to control invasive species and conserve native animal species.

- **Standard ZOOL.3.1** **Obtain, evaluate, and communicate** how animal structures are used in different societies. Examples of structures could include muscle, blood, bones, or other tissues and organs. Examples of uses could include food, medicine, or biotechnology.

- **Standard ZOOL.3.2** **Ask questions and define problems** to identify the cause and effect of human activities on natural habitats and populations of animals. Emphasize how individuals, state, and local management plans, and government legislation have identified and adjusted practice to reduce and/or reverse these impacts. Examples of human activities could include habitat destruction, overharvesting, water consumption, or pollution.

- **Standard ZOOL.3.3** **Evaluate** current plans to manage the control of an invasive animal species in Utah or to manage the conservation of a native animal species in Utah focusing on the population's proportion and quantity. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine if the plan is an optimal solution.* Emphasize the impact that the animal species has on its environment.

APPENDIX
SCIENCE
WITH ENGINEERING EDUCATION (SEEd) STANDARDS

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K-12 PROGRESSIONS

Research from *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), the foundational document from which the Utah SEEd Standards were developed, "emphasizes developing students' proficiency in science in a coherent way across grades K–12 following the logic of learning progressions" (p. 33). This document emphasizes that learning progressions are necessary for all three dimensions delineated in the report: Science and Engineering Practices (SEPs), Crosscutting Concepts (CCCs), and Disciplinary Core Ideas (DCIs).

As a support for educators, The National Science Teaching Association (NSTA) has provided general learning progressions in a matrix format that adhere to the outlined learning progression endpoints described in the *Framework* (NRC, 2012) document. These Matrices visually display a coherent progression of the SEPs, CCCs, and DCIs through the K–2, 3–5, 6–8, and 9–12 grade bands.

The SEP, CCC, and DCI learning progressions for each Utah SEEd Standards are specifically delineated within the grade-level Core Guides. They were developed by teams of Utah Educators with the USBE education specialists to serve as a resource for Utah teachers as they consider classroom instruction aligned to the standards. The DCI progressions for the K–12 Utah SEEd Standards can be found in this document: K–12 SEEd DCI Science Concept Progressions.

This document provides the more general SEP and CCC learning progressions developed by NSTA and adapted within the Utah Science Core Guides. The learning progressions of the SEPs and CCCs for each Utah SEEd Standard are slightly different from the generic model to account for how the three dimensions work together in a specific context. The following SEP matrices are color-coded in Blue, and the CCC matrices are color-coded in green.

Asking Questions and Defining Problems

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested. Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas.

K–2	3–5
Ask questions based on observations to find more information about the natural and/or designed world(s).	Ask questions about what would happen if a variable is changed.
Ask and/or identify questions that can be answered by an investigation.	Identify scientific (testable) and nonscientific (non-testable) questions. Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause-and-effect relationships.
[Intentionally left blank]	[Intentionally left blank]
Define a simple problem that can be solved through the development of a new or improved object or tool.	Use prior knowledge to describe problems that can be solved. Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.

6–8	9–12
Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument. Ask questions to determine relationships between independent and dependent variables and relationships in models. Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.	Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables. Ask questions to clarify and refine a model, an explanation, or an engineering problem.
Ask questions that require sufficient and appropriate empirical evidence to answer. Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	Evaluate a question to determine if it is testable and relevant. Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.	Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of the design.
Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.

Developing and Using Models

A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions, and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.

K-2	3–5
Distinguish between a model and the actual object, process, and/or events the model represents. Compare models to identify common features and differences.	Identify limitations of models.
Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).	Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. Develop and/or use models to describe and/or predict phenomena.
Develop a simple model based on evidence to represent a proposed object or tool.	Develop a diagram or simple physical prototype to convey a proposed object, tool, or process. Use a model to test cause-and-effect relationships or interactions concerning the functioning of a natural or designed system.

6-8	9–12
Evaluate limitations of a model for a proposed object or tool.	Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. Design a test of a model to ascertain its reliability.
Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed. Use and/or develop a model of simple systems with uncertain and less predictable factors. Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. Develop and/or use a model to predict and/or describe phenomena. Develop a model to describe unobservable mechanisms.	Develop, revise, and/or use a model based on evidence to illustrate and/ or predict the relationships between systems or between components of a system. Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.
Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.	Develop a complex model that allows for manipulation and testing of a proposed process or system. Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Planning and Carrying Out Investigations

Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.

K-2	3–5
With guidance, plan and conduct an investigation in collaboration with peers (for K). Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.	Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
Evaluate different ways of observing and/or measuring a phenomenon to determine which way can answer a question.	Evaluate appropriate methods and/or tools for collecting data.
Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons. Make observations (firsthand or from media) and/or measurements of a proposed object or tool or solution to determine if it solves a problem or meets a goal. Make predictions based on prior experiences.	Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. Make predictions about what would happen if a variable changes. Test two different models of the same proposed object, tool, or process to determine which better meets criteria for success.

6-8	9–12
Plan an investigation individually and collaboratively, and in the design identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.	Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible variables or effects and evaluate the confounding investigation's design to ensure variables are controlled. Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time); refine the design accordingly. Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.
Evaluate the accuracy of various methods for collecting data.	Select appropriate tools to collect, record, analyze, and evaluate data.
Collect and produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. Collect data about the performance of a proposed object, tool, process, or system under a range of conditions.	Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.

Analyzing and Interpreting Data

Scientific investigations produce data that must be analyzed to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology ►►

K–2	3–5
Record information (observations, thoughts, and ideas). Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world in order to answer scientific questions and solve problems. Compare predictions (based on prior experiences) to what occurred (observable events).	Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships.
[Intentionally left blank]	Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.
[Intentionally left blank]	[Intentionally left blank]
[Intentionally left blank]	Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
Analyze data from tests of an object or tool to determine if it works as intended.	Analyze data to refine a problem statement or the design of a proposed object, tool, or process. Use data to evaluate and refine design solutions.

▶▶makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.

6–8	9–12
Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. Distinguish between causal and correlational relationships in data. Analyze and interpret data to provide evidence for phenomena.	Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.	Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
Consider limitations of data analysis (e.g., measurement error) and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).	Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.
Analyze and interpret data to determine similarities and differences in findings.	Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
Analyze data to define an optimal operational range for a proposed object, tool, process, or system that best meets criteria for success.	Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.

Using Mathematics and Computational Thinking

In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions.

K–2	3–5
[Intentionally left blank]	[Intentionally left blank]
Use counting and numbers to identify and describe patterns in the natural and designed world(s).	Organize simple data sets to reveal patterns that suggest relationships.
Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.	Describe, measure, estimate, and/or graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems.
Use quantitative data to compare two alternative solutions to a problem.	Create and/or use graphs and/or charts generated from simple algorithms to compare alternative solutions to an engineering problem.

6–8	9–12
Decide when to use qualitative vs. quantitative data.	Decide if qualitative or quantitative data are best to determine whether a proposed object or tool meets criteria for success.
Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.	Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.
Use mathematical representations to describe and/or support scientific conclusions and design solutions.	Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
Create algorithms (a series of ordered steps) to solve a problem. Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems. Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.	Apply techniques of algebra and functions to represent and solve scientific and engineering problems. Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (e.g., mg/mL, kg/m^3, acre-feet).

Constructing Explanations and Designing Solutions

The end-products of science are explanations and the end-products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.

K–2	3–5
Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.	Construct an explanation of observed relationships (e.g., the distribution of plants in the backyard).
[Intentionally left blank]	Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
[Intentionally left blank]	Identify the evidence that supports particular points in an explanation.
Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem. Generate and/or compare multiple solutions to a problem.	Apply scientific ideas to solve design problems. Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.

6–8	9–12
Construct an explanation that includes qualitative or quantitative relationships between variables that predict and/or describe phenomena. Construct an explanation using models or representations.	Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables
Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.	Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.	Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process, or system. Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. Optimize performance of a design by prioritizing criteria, making trade-offs, testing, revising, and retesting.	Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

Engaging in Argument from Evidence

Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims.

K–2	3–5
Identify arguments that are supported by evidence. Distinguish between explanations that account for all gathered evidence and those that do not. Analyze why some evidence is relevant to a scientific question and some is not. Distinguish between opinions and evidence in one's own explanations.	Compare and refine arguments based on an evaluation of the evidence presented. Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation.
Listen actively to arguments to indicate agreement or disagreement based on evidence, and/or to retell the main points of the argument.	Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.
Construct an argument with evidence to support a claim.	Construct and/or support an argument with evidence, data, and/or a model. Use data to evaluate claims about cause and effect.
Make a claim about the effectiveness of an object, tool, or solution that is supported by relevant evidence.	Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.

6–8	9–12
Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.	Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.	Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.
Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.	Construct, use, and/or present an oral and written argument or counter arguments based on data and evidence.
Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system, based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints. Evaluate competing design solutions based on jointly developed and agreed upon design criteria.	Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Obtaining, Evaluating, and Communicating Information

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs.

K–2	3–5
Read grade-appropriate texts and/or use media to obtain scientific and/or technical information to determine patterns in and/or evidence about the natural and designed world(s).	Read and comprehend grade appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence. Compare and/or combine across complex texts and/or other reliable media to support the engagement in other scientific and/or engineering practices.
Describe how specific images (e.g., a diagram showing how a machine works) support a scientific or engineering idea.	Combine information in written text with that contained in corresponding tables, diagrams, and/or charts to support the engagement in other scientific and/or engineering practices.
Obtain information using various texts, text features (e.g., headings, tables of contents, glossaries, electronic menus, icons), and other media that will be useful in answering a scientific question and/or supporting a scientific claim.	Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.
Communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers that provide detail about scientific ideas, practices, and/or design ideas.	Communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts.

6–8	9–12
Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).	Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings.	Compare, integrate, and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts.	Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.	Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Patterns

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

K–2	3–5	6–8	9–12
Patterns in the natural and human-designed world can be observed, used to describe phenomena, and used as evidence.	Similarities and differences in patterns can be used to sort, classify, communicate, and analyze simple rates of change for natural phenomena and designed products. Patterns of change can be used to make predictions. Patterns can be used as evidence to support an explanation.	Macroscopic patterns are related tothe nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs, charts, and images can be used to identify patterns in data.	Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced, thus requiring improved investigations and experiments. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Mathematical representations are needed to identify some patterns. Empirical evidence is needed to identify patterns.

Cause and Effect

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

K–2	3–5	6–8	9–12
Events have causes that generate observable patterns. Simple tests can be designed to gather evidence to support or refute student ideas about causes.	Cause-and-effect relationships are routinely identified, tested, and used to explain change. Events that occur together with regularity might or might not be a cause-and-effect relationship.	Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause-and-effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause-and-effect relationships in systems can only be described using probability.	Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause-and-effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects.

Scale, Proportion, and Quantity

In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

K–2	3–5	6–8	9–12
Relative scales allow objects and events to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower). Standard units are used to measure length.	Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods. Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.	Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale. Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. Phenomena that can be observed at one scale may not be observable at another scale.	The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. Some systems can only be studied indirectly because they are too small, too large, too fast, or too slow to observe directly. Patterns observable at one scale may not be observable or exist at other scales. Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

System and System Models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

K–2	3–5	6–8	9–12
Objects and organisms can be described in terms of their parts. Systems in the natural and designed world have parts that work together.	A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. A system can be described in terms of its components and their interactions.	Systems may interact with other systems; they may have subsystems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study.	Systems can be designed to do specific tasks. When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Energy and Matter

Tracking energy and matter flows into, out of, and within systems helps one understand their system's behavior.

K–2	3–5	6–8	9–12
Objects may break into smaller pieces, be put together into larger pieces, or change shapes.	Matter is made of particles. Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. Energy can be transferred in various ways and between objects.	Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system.	The total amount of energy and matter in closed systems is conserved. Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Energy cannot be created or destroyed— it only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Structure and Function

The way an object is shaped or structured determines many of its properties and functions.

K–2	3–5	6–8	9–12
The shape and stability of structures of natural and designed objects are related to their function(s).	Different materials have different substructures, which can sometimes be observed. Substructures have shapes and parts that serve functions.	Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.	Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal their function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of their various materials.

Stability and Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

K–2	3–5	6–8	9–12
Some things stay the same while other things change. Things may change slowly or rapidly.	Change is measured in terms of differences over time and may occur at different rates. Some systems appear stable, but over long periods of time will eventually change.	Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed by either sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.	Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability.

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