UTAH CORE STANDARDS

UTAH SCIENCE WITH ENGINEERING EDUCATION (SEEd) STANDARDS

UTAH STATE BOARD OF EDUCATION 250 EAST 500 SOUTH P.O. BOX 144200 SALT LAKE CITY, UTAH 84114-4200 SYDNEE DICKSON, ED.D., STATE SUPERINTENDENT OF PUBLIC INSTRUCTION

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

Grades 6–8 Standards
Adopted December 2015

Grades K–2, 3–5, High School (Biology, Chemistry, Earth and Space Science, and Physics) Standards
Adopted June 2019

by the

Utah State Board of Education
250 East 500 South
P.O. Box 144200
Salt Lake City, UT 84114-4200

Sydnee Dickson, Ed.D.
State Superintendent of Public Instruction

https://www.schools.utah.gov

The Utah State Board of Education, in January of 1984, established policy requiring the identification of specific core standards to be met by all K–12 students in order to graduate from Utah's secondary schools. The Utah State Board of Education regularly updates the Utah Core Standards, while parents, teachers, and local school boards continue to control the curriculum choices that reflect local values.

The Utah Core Standards are aligned to scientifically based content standards. They drive high quality instruction through statewide comprehensive expectations for all students. The standards outline essential knowledge, concepts, and skills to be mastered at each grade level or within a critical content area. The standards provide a foundation for ensuring learning within the classroom.

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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.	Patterns: Students observe patterns to organize and classify factors that influence relationships	Physical Sciences: (PS1) Matter and Its Interactions (PS2) Motion and Stability: Forces and Interactions (PS3) Energy (PS4) Waves
Developing and using models: Students develop physical, conceptual, and other models to represent relationships, explain mechanisms, and predict outcomes.	Cause and effect: Students investigate and explain causal relationships in order to make tests and predictions.	Life Sciences: (LS1) Molecules to Organisms (LS2) Ecosystems (LS3) Heredity (LS4) Biological Evolution
Planning and carrying out investigations: Students plan and conduct scientific investigations in order to test, revise, or develop explanations.	Scale, proportion, and quantity: Students compare the scale, proportions, and quantities of measurements within and between various systems.	Earth and Space Sciences: (ESS1) Earth's Place in the Universe (ESS2) Earth's Systems (ESS3) Earth and Human Activity
Analyzing and interpreting data: Students analyze various types of data in order to create valid interpretations or to assess claims/conclusions.	Systems and system models: Students use models to explain the parameters and relationships that describe complex systems.	Engineering Design: (ETS1.A) Defining and Delimiting an Engineering Problem (ETS1.B) Developing Possible Solutions (ETS1.C) Optimizing the Design Solution
Using mathematics and computational thinking: Students use fundamental tools in science to compute relationships and interpret results.	Energy and matter: Students describe cycling of matter and flow of energy through systems, including transfer, transformation, and conservation of energy and matter.	
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.	Structure and function: Students relate the shape and structure of an object or living thing to its properties and functions.	
Engaging in argument from evidence: Students support their best explanations with lines of reasoning using evidence to defend their claims.	Stability and change: Students evaluate how and why a natural or constructed system can change or remain stable over time.	
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.		

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

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)

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