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
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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. **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

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

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)

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