Colorado
Academic Standards

Science

High School

COLORADO
Department of Education

ALL STUDENTS • ALL STANDARDS

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Purpose of Science

"Science is facts; just as houses are made of stone, so is science made of facts; but a pile of stones is not a house, and a collection of facts is not necessarily science."
--Jules Henri Poincaré (1854-1912) French mathematician

High expectations in education are essential for the U.S. to continue as a world leader in the 21st century. In order to be successful in postsecondary education, the workforce, and in life, students need a rigorous, age-appropriate set of standards that include finding and gathering information, critical thinking, and reasoning skills to evaluate information, and use information in social and cultural contexts. Students must learn to comprehend and process information, analyze and draw conclusions, and apply the results to everyday life.

A quality science education embodies 21st century skills and postsecondary and workforce readiness by teaching students critical skills and thought processes to meet the challenges of today's world. Scientifically literate graduates will help to ensure Colorado's economic vitality by encouraging the development of research and technology, managing and preserving our environmental treasures, and caring for the health and well-being of our citizens.

Science is both a body of knowledge that represents the current understanding of natural systems, and the process whereby that body of knowledge has been established and is continually extended, refined, and revised. Because science is both the knowledge of the natural world and the processes that have established this knowledge, science education must address both of these aspects.

At a time when pseudo-scientific ideas and outright fraud are becoming more common place, developing the skepticism and critical thinking skills of science gives students vital skills needed to make informed decisions about their health, the environment, and other scientific issues facing society. A major aspect of science is the continual interpretation of evidence. All scientific ideas constantly are being challenged by new evidence and are evolving to fit the new evidence. Students must understand the collaborative social processes that guide these changes so they can reason through and think critically about popular scientific information, and draw valid conclusions based on evidence, which often is limited. Imbedded in the cognitive process, students learn and apply the social and cultural skills expected of all citizens in school and in the workplace. For example, during class activities, laboratory exercises, and projects, students learn and practice self-discipline, collaboration, and working in groups.

The Colorado Academic Standards in science represent what all Colorado students should know and be able to do in science as a result of their preschool through twelfth-grade science education. Specific expectations are given for students who complete each grade from preschool through eighth grade and for high school. These standards outline the essential level of science content knowledge and the application of the skills needed by all Colorado citizens to participate productively in our increasingly global, information-driven society.

Prepared Graduates in Science

1. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding structure, properties and interactions of matter.
2. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding interactions between objects and within systems of objects.
3. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how energy is transferred and conserved.
4. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how waves are used to transfer energy and information.
5. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how individual organisms are configured and how these structures function to support life, growth, behavior and reproduction.
6. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how living systems interact with the biotic and abiotic environment.
7. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how genetic and environmental factors influence variation of organisms across generations.
8. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how natural selection drives biological evolution accounting for the unity and diversity of organisms.
9. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding the universe and Earth's place in it.
10. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how and why Earth is constantly changing.
11. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how human activities and the Earth's surface processes interact.

Standards in Science

Standards are the topical organization of an academic content area. The three standards of science, including the disciplinary core ideas, are:

1. Physical Science

Students know and understand common properties, forms, and changes in matter and energy.

- PS1 Matter and Its Interactions
- PS2 Motion and Stability: Forces and Interactions
- PS3 Energy
- PS4 Waves and Their Applications in Technologies for Information Transfer

2. Life Science

Students know and understand the characteristics and structure of living things, the processes of life, and how living things interact with each other and their environment.

- LS1 From Molecules to Organisms: Structures and Processes
- LS2 Ecosystems: Interactions, Energy, and Dynamics
- LS3 Heredity: Inheritance and Variation of Traits
- LS4 Biological Evolution: Unity and Diversity

3. Earth and Space Science

Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space.

- ESS1 Earth’s Place in the Universe
- ESS2 Earth’s Systems
- ESS3 Earth ad Human Activity

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Cross Cutting Concepts

1. *Patterns.* Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
2. *Cause and effect: Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
3. *Scale, proportion, and quantity.* In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
4. *Systems and system models.* Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. *Energy and matter: Flows, cycles, and conservation.* Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
6. *Structure and function.* The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
7. *Stability and change.* For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

How to Read the Colorado Academic Standards

CONTENT AREA
Grade Level, Standard Category

COLORADO Department of Education

Prepared Graduates:

The *PG Statements* represent concepts and skills that all students who complete the Colorado education system must master to ensure their success in postsecondary and workforce settings.

Grade Level Expectation:

The *GLEs* are an articulation of the concepts and skills for a grade, grade band, or range that students must master to ensure their progress toward becoming a prepared graduate.

Evidence Outcomes

The *EOs* describe the evidence that demonstrates that a student is meeting the GLE at a mastery level.

Academic Context and Connections

The *ACCs* provide context for interpreting, connecting, and applying the content and skills of the GLE. This includes the *Colorado Essential Skills*, which are the critical skills needed to prepare students to successfully enter the workforce or educational opportunities beyond high school embedded within statute (C.R.S. 22-7-1005) and identified by the Colorado Workforce Development Committee.

The ACCs contain information unique to each content area. Content-specific elements of the ACCs are described below.

Content Area

Grade Level, Standard Category 2020 Colorado Academic Standards GLE Code

Academic Context and Connections in Science:

Colorado Essential Skills and Science and Engineering Practices: These statements describe how the learning of the content and skills described by the GLE and EOs connects to and supports the development of the *Colorado Essential Skills* named in the parentheses. The science and engineering practices are things that scientists employ as they investigate and build models and theories about the world. These terms are used to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice.

Elaboration on the GLE: This section provides greater context for the GLE through a description of the understanding about the core ideas that should be developed by students.

Cross Cutting Concepts: The crosscutting concepts have application across all domains of science. As such, they provide one way of linking across the domains through core ideas.

Prepared Graduates:

1. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding structure, properties and interactions of matter.

Grade Level Expectation:

1. The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter.

Evidence Outcomes

Students Can:

a. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy levels of atoms. (HS-PS1-1)*(Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.) (Boundary Statement: Limited to main group elements. Does not include quantitative understanding of ionization energy beyond relative trends.)*

b. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. (HS-PS1-3)*(Clarification Statement: Emphasis is on understanding the difference intermolecular versus intramolecular forces and the strengths of forces between particles but not naming specific intermolecular forces, such as dipole-dipole. Examples of particles could include ions, atoms, molecules, and networked materials, such as graphite. Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.) (Boundary Statement: Does not include Raoult's law calculations of vapor pressure or the names, shapes, or bond angles associated with VSEPR theory.)*

c. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. (HS-PS1-4) *(Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.) (Boundary Statement: Does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Use a model to predict the relationships between systems or between components of a system. (Developing and Using Models) (Personal: Initiative/Self-direction)
2. 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), and refine the design accordingly (Planning and Carrying Out Investigations) (Personal: Personal responsibility)

Elaboration on the GLE:

1. Students can answer the question: How do particles combine to form the variety of matter one observes?

2. PS1:A Structure and Properties of Matter: Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

Cross Cutting Concepts:

1. Patterns: 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.

Prepared Graduates:

1. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding structure, properties and interactions of matter.

Grade Level Expectation:

2. Chemical processes, their rates, their outcomes, and whether or not energy is stored or released can be understood in terms of collisions of molecules, rearrangement of atoms, and changes in energy as determined by properties of elements involved.

Evidence Outcomes

Students Can:

a. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. (HS-PS1-2) *(Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.) (Boundary Statement: Limited to chemical reactions involving main group elements and combustion reactions).*

b. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. (HS-PS1-4) *(Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.) (Boundary Statement: Does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.)*

c. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. (HS-PS1-5) *(Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.) (Boundary Statement: Limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.)*

d. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. (HS-PS1-6) *(Clarification Statement: Emphasis is on the application of Le Chatlier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.) (Boundary Statement: Limited to specifying the change in only one variable at a time. Does not include calculating equilibrium constants and concentrations.)*

e. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. (HS-PS1-7) *(Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.) (Boundary Statement: Does not include complex chemical reactions or calculations involving limiting and excess reactants.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. 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 principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. (Constructing Explanations and Designing Solutions) (Civic/Interpersonal: Civic Engagement)
2. Develop a model based on evidence to illustrate the relationships between systems or between components of a system (Developing and Using Models) (Personal: Personal responsibility)
3. Use mathematical representations of phenomena to support claims (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)

Elaboration on the GLE:

1. Students can answer the questions: How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?
2. PS1:B Chemical Reactions: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. 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. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Cross Cutting Concepts:

1. Patterns: 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.
2. Energy and Matter: 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.
3. Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable.
4. Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Science assumes the universe is a vast single system in which basic laws are consistent.

Prepared Graduates:

1. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding structure, properties and interactions of matter.

Grade Level Expectation:

3. The strong nuclear interaction provides the primary force that holds nuclei together. Nuclear processes including fusion, fission, and radioactive decays of unstable nuclei involve changes in nuclear binding energies.

Evidence Outcomes

Students Can:

a. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. (HS-PS1-8) *(Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams and on the scale of energy released in nuclear processes relative to other kinds of transformations. Quantitative models for radioactive decay should not require mathematical manipulations of an exponential equation.) (Boundary Statement: Does not include quantitative calculation of energy released. Limited to alpha, beta, and gamma radioactive decays.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (Developing and Using Models) (Personal: Initiative/Self-direction)

Elaboration on the GLE:

1. Students can answer the question: What forces hold nuclei together and mediate nuclear processes?
2. PS1:C Nuclear Processes: Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.

Cross Cutting Concepts:

1. Energy and Matter: In nuclear processes, atoms are not conserved, but the total number of neutrons plus protons is conserved.

Prepared Graduates:

2. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding interactions between objects and within systems of objects.

Grade Level Expectation:

4. Newton's second law and the conservation of momentum can be used to predict changes in the motion of macroscopic objects.

Evidence Outcomes

Students Can:

a. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. (HS-PS2-1) *(Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.). (Boundary Statement: Limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.)*
b. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. (HS-PS2-2) *(Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.) (Boundary Statement: Limited to systems of two macroscopic bodies moving in one dimension.)*
c. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. (HS-PS2-3) *(Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.) (Boundary Statement: Limited to qualitative evaluations and/or algebraic manipulations.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. 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. (Analyzing and Interpreting Data) (Entrepreneurial: Critical thinking/Problem solving)
2. Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (Constructing Explanations and Designing Solution) (Personal: Personal responsibility)
3. Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Science assumes the universe is a vast single system in which basic laws are consistent.
4. Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena. Theories and laws provide explanations in science. Laws are statements or descriptions of the relationships among observable phenomena.

Elaboration on the GLE:

1. Students can answer the question: How can one predict an object's continued motion, changes in motion, or stability?
2. PS2:A Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. 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.

Cross Cutting Concepts:

1. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Systems can be designed to cause a desired effect.
2. Systems and System Models: When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Prepared Graduates:

2. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding interactions between objects and within systems of objects.

Grade Level Expectation:

5. Forces at a distance are explained by fields that can transfer energy and can be described in terms of the arrangement and properties of the interacting objects and the distance between them.

Evidence Outcomes

Students Can:

a. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. (HS-PS2-4) *(Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.) (Boundary Statement: Limited to systems with two objects and basic algebraic substitution and/or manipulations.)*
b. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. (HS-PS2-5) *(Boundary Statement: Limited to designing and conducting investigations with provided materials and tools.)*
c. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. (HS-PS2-6) *(Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.) (Boundary Statement: Limited to provided molecular structures of specific designed materials.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. 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), and refine the design accordingly. (Plan and Carry Out an Investigation) (Entrepreneurial: Inquiry/Analysis)
2. Use mathematical representations of phenomena to describe explanations. (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)
3. Communicate scientific and technical information (e.g., about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (Obtaining, Evaluating, and Communicating Information) (Professional: Information and Communications Technologies)
4. Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena. Theories and laws provide explanations in science. Laws are statements or descriptions of the relationships among observable phenomena.

Elaboration on the GLE:

1. Students can answer the question: What underlying forces explain the variety of interactions observed?
2. PS2:B Types of Interactions: Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

Cross Cutting Concepts:

1. Patterns: 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.
2. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
3. Structure and Function: 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 its function and/or solve a problem.

Prepared Graduates:

3. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how energy is transferred and conserved.

Grade Level Expectation:

6. Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.

Evidence Outcomes

Students Can:

a. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. (HS-PS3-1) *(Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.) (Boundary Statement: Limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.)*

b. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects). (HS-PS3-2) *(Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the Earth, and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.)*

c. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. (HS-PS3-3) *(Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices and on the ability of energy to be transferred but not on the efficiency of energy transfer. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.) (Boundary Statement: Quantitative evaluations are limited to total output for a given input, and are limited to devices constructed with materials provided to students.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (Developing and Using Models) (Personal: Personal responsibility)
2. Create a computational model or simulation of a phenomenon, designed device, process, or system. (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)

Elaboration on the GLE:

1. Students can answer the question: What is energy?
2. PS3:A Definitions of Energy: Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

Cross Cutting Concepts:

1. System and System Models: 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.
2. Constructing Explanations and Designing Solutions: Design, evaluate, and/or refine a solution to complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.
3. Energy and Matter: 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 — only moves between one place and another place, between objects and/or fields, or between systems.
4. Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World. Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
5. Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Science assumes the universe is a vast single system in which basic laws are consistent.

Prepared Graduates:

3. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how energy is transferred and conserved.

Grade Level Expectation:

7. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

Evidence Outcomes

Students Can:

a. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. (HS-PS3-1) *(Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.) (Boundary Statement: Limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.)*
b. 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 (second law of thermodynamics). (HS-PS3-4) *(Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.) (Boundary Statement: Limited to investigations based on materials and tools provided to students.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Create a computational model or simulation of a phenomenon, designed device, process, or system. (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)
2. 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), and refine the design accordingly. (Planning and Carrying Out Investigations) (Entrepreneurial: Inquiry/Analysis)

Elaboration on the GLE:

1. Students can answer the questions: What is meant by conservation of energy? How is energy transferred between objects or systems?

2. PS3:B Conservation of Energy and Energy Transfer: Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. The availability of energy limits what can occur in any system. Uncontrolled systems always evolve toward more stable states — that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

Cross Cutting Concepts:

1. Systems and Systems Models: 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 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.
2. Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Science assumes the universe is a vast single system in which basic laws are consistent.

Prepared Graduates:

3. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how energy is transferred and conserved.

Grade Level Expectation:

8. Force fields (gravitational, electric, and magnetic) contain energy and can transmit energy across space from one object to another.

Evidence Outcomes

Students Can:

a. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. (HS-PS3-5) *(Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.) (Boundary Statement: Limited to systems containing two objects.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (Developing and Using Models) (Personal: Initiative/Self-direction)

Elaboration on the GLE:

1. Students can answer the question: How are forces related to energy?
2. PS3:C Relationship Between Energy and Forces: When two objects interacting through a field change relative position, the energy stored in the field is changed.

Cross Cutting Concepts:

1. Cause and Effect: 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.

Prepared Graduates:

3. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how energy is transferred and conserved.

Grade Level Expectation:

9. Although energy cannot be destroyed, it can be converted to less useful forms as it is captured, stored and transferred.

Evidence Outcomes

Students Can:

a. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. (HS-PS3-3) *(Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices, including the identification of different energy types [starting points] and how they are transferred. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.) (Boundary Statement: Quantitative evaluation is limited to total output for a given input. Limited to devices constructed with materials provided to students.)*
b. 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 (second law of thermodynamics). (HS-PS3-4) *(Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.) (Boundary Statement: Limited to investigations based on materials and tools provided to students.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Design, evaluate, and/or refine a solution to complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. (Constructing Explanations and Designing Solutions) (Civic/Interpersonal: Civic engagement)
2. 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), and refine the design accordingly. (Planning on Carrying Out Investigations) (Personal: Initiative/Self-direction)

Elaboration on the GLE:

1. Students can answer the questions: How do food and fuel provide energy? If energy is conserved, why do people say it is produced or used?
2. PS3:D Energy in Chemical Processes and Everyday Life: Although energy cannot be destroyed, it can be converted to less useful forms — for example, to thermal energy in the surrounding environment.

Cross Cutting Concepts:

1. Energy and Matter: 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.
2. Systems and Systems Models: 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.

Prepared Graduates:

4. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how waves are used to transfer energy and information.

Grade Level Expectation:

10. Waves have characteristic properties and behaviors.

Evidence Outcomes

Students Can:

a. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. (HS-PS4-1) *(Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.) (Boundary Statement: Limited to algebraic relationships and describing those relationships qualitatively.)*

b. Evaluate questions about the advantages of using a digital transmission and storage of information. (HS-PS4-2) *(Clarification Statement: Examples of advantages [compared to waves] could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (Asking Questions and Defining Problems) (Entrepreneurial: Inquiry/Analysis)
2. Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)
3. Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (Engaging in Argument from Evidence) (Personal: Initiative/Self-direction)
4. Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena. A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

Elaboration on the GLE:

1. Students can answer the question: What are the characteristic properties and behaviors of waves?
2. PS4:A Wave Properties: 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 is passing. Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary Statement: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)

Cross Cutting Concepts:

1. Energy and Matter: 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.
2. Systems and Systems Models: 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.

Prepared Graduates:

4. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how waves are used to transfer energy and information.

Grade Level Expectation:

11. Both an electromagnetic wave model and a photon model explain features of electromagnetic radiation broadly and describe common applications of electromagnetic radiation.

Evidence Outcomes

Students Can:

a. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. (HS-PS4-3) *(Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.) (Boundary Statement: Does not include using quantum theory.)*

b. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. (HS-PS4-4) *(Clarification Statement: Emphasis is on the idea that different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Some examples may include: sunscreen SPF, lasers stimulating particular material to resonate at a particular frequency, and a discussion of how color is perceived as it relates to frequency. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.)*

c. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. (HS-PS4-5) *(Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.) (Boundary Statement: Limited to qualitative information and does not include band theory.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (Engaging in Argument from Evidence) (Personal: Initiative/Self-direction)
2. Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate 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). (Obtaining, Evaluating, and Communicating Information) (Entrepreneurial: Inquiry/Analysis)

3. Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena. A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

Elaboration on the GLE:

1. Students can answer the questions: What is light? How can one explain the varied effects that involve light? What other forms of electromagnetic radiation are there?
2. PS4:B Electromagnetic Radiation: Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-ray s, gamma rays) can ionize atoms and cause damage to living cells. Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

Cross Cutting Concepts:

1. Cause and Effect: 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.
2. Systems and System 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.
3. Connections to Engineering, Technology, and Applications of Science: Interdependence of Science, Engineering, and Technology. Science and engineering complement each other in the cycle known as research and development (R&D).
4. Influence of Engineering, Technology, and Science on Society and the Natural World: Modern civilization depends on major technological systems.

Prepared Graduates:

4. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how waves are used to transfer energy and information.

Grade Level Expectation:

12. Multiple technologies that are part of everyday experiences are based on waves and their interactions with matter.

Evidence Outcomes

Students Can:

a. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. (HS-PS4-5) *(Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.) (Boundary Statement: Limited to qualitative information. Does not include band theory.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Communicate 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). (Obtaining, Evaluating, and Communicating Information) (Professional: Information literacy)
2. Influence of Engineering, Technology, and Science on Society and the Natural World: Modern civilization depends on major technological systems.

Elaboration on the GLE:

1. Students can answer the question: How are instruments that transmit and detect waves used to extend human senses?
2. PS4:C Information Technologies and Instrumentation: Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

Cross Cutting Concepts:

1. Cause and Effect: Systems can be designed to cause a desired effect.
2. Connections to Engineering, Technology, and Applications of Science: Interdependence of Science, Engineering, and Technology: Science and engineering complement each other in the cycle known as research and development (R&D).

Prepared Graduates:

5. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how individual organisms are configured and how these structures function to support life, growth, behavior and reproduction.

Grade Level Expectation:

1. DNA codes for the complex hierarchical organization of systems that enable life's functions.

Evidence Outcomes

Students Can:

a. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. (HS-LS1-1) *(Boundary Statement: Does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.)*
b. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. (HS-LS1-2) *(Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.) (Boundary Statement: Does not include interactions and functions at the molecular or chemical reaction level.)*
c. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. (HS-LS1-3) *(Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.) (Boundary Statement: Does not include the cellular processes involved in the feedback mechanism.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Develop and use a model based on evidence to illustrate the relationship between systems or between components of a system. (Developing and Using Models) (Personal: Initiative/Self-direction)
2. 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 traits, cost, risk, time), and refine the design accordingly. (Planning and Carrying Out Investigations) (Entrepreneurial: Inquiry/Analysis)
3. Construct an explanation based on valid and reliable evidence obtained from a variety 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. (Constructing Explanations and Designing Solutions) (Civic/Interpersonal: Global/Cultural awareness)

Elaboration on the GLE:

1. Students can answer the question: How do the structures of organisms enable life's functions?
2. LS1:A Structure and Function: Systems of specialized cells within organisms help them perform the essential functions of life. All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

Cross Cutting Concepts:

1. Systems and System Models: Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions – including energy, matter, and information flows – within and between systems at different scales.
2. Structure and Function: Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components to reveal the structure's function and/or to solve a problem.
3. Stability and Change: Feedback (negative or positive) can stabilize or destabilize a system.

COLORADO Department of Education

Prepared Graduates:

5. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how individual organisms are configured and how these structures function to support life, growth, behavior and reproduction.

Grade Level Expectation:

2. Growth and division of cells in complex organisms occurs by mitosis, which differentiates specific cell types.

Evidence Outcomes

Students Can:

a. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. (HS-LS1-4) *(Boundary Statement: Does not include specific gene control mechanisms or rote memorization of the steps of mitosis.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Use a model based on evidence to illustrate the relationships between systems or between components of systems. (Developing and Using Models) (Professional: Information and Communications Technologies)

Elaboration on the GLE:

1. Students can answer the question: How do organisms grow and develop?
2. LS1:B Growth and Development of Organisms: In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.

Cross Cutting Concepts:

1. Systems and System Models: Models (e.g., physical, mathematical, computer) can be used to stimulate systems and interactions – including energy, matter, and information flows – within and between systems at different scales.
2. Structure and Function: Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components to reveal the structure's function and/or to solve a problem.
3. Stability and Change: Feedback (negative or positive) can stabilize or destabilize a system.

Prepared Graduates:

5. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how individual organisms are configured and how these structures function to support life, growth, behavior and reproduction.

Grade Level Expectation:

3. Organisms use matter and energy to live and grow.

Evidence Outcomes

Students Can:

a. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. (HS-LS1-5) *(Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.) (Boundary Statement: Does not include specific biochemical steps.)*
b. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. (HS-LS1-6) *(Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.) (Boundary Statement: Does not include the details of the specific chemical reactions or identification of macromolecules.)*
c. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. (HS-LS1-7) *(Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Use a model based on evidence to illustrate the relationships between systems or between components of systems. (Developing and Using Models) (Personal: Initiative/Self-direction)
2. 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 would operate today as they did the past and will continue to do so in the future. (Constructing Explanations and Designing Solutions) (Entrepreneurial: Creativity/Innovation)

Elaboration on the GLE:

1. Students can answer the question: How do organisms obtain and use the matter and energy they need to live and grow?
2. LS1:C Organization for Matter and Energy Flow in Organisms: The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. The sugar molecules thus formed contain carbon, hydrogen, and oxygen: Their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another and release energy to the surrounding environment and to maintain body temperature. Cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles.

Cross Cutting Concepts:

1. Energy and matter: 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.

Prepared Graduates:

6. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how living systems interact with the biotic and abiotic environment.

Grade Level Expectation:

4. Organisms interact with the living and nonliving components of the environment to obtain matter and energy.

Evidence Outcomes

Students Can:

a. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. (HS-LS2-1) *(Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.)*

b. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. (HS-LS2-2) *(Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (Using Mathematical and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)
2. Connections to Nature of Science: Scientific Knowledge is open to revision in light of new evidence. Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.

Elaboration on the GLE:

1. Students can answer the question: How do organisms interact with the living and nonliving environments to obtain matter and energy?
2. LS2:A Interdependent Relationships in Ecosystems: Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.
3. LS2:C Ecosystem Dynamics, Functioning, and Resilience: A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.

Cross Cutting Concepts:

1. Scale, Proportion, and Quantity: The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Prepared Graduates:

6. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how living systems interact with the biotic and abiotic environment.

Grade Level Expectation:

5. Matter and energy necessary for life are conserved as they move through ecosystems.

Evidence Outcomes

Students Can:

a. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. (HS-LS2-3) *(Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.)*
b. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. (HS-LS2-4) *(Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.)*
c. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. (HS-LS2-5) *(Clarification Statement: Examples of models could include simulations and mathematical models.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. 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. (Constructing Explanations and Revising Solution) (Entrepreneurial: Creativity/Innovation)
2. Use mathematical representations of phenomena or design solutions to support claims. (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)
3. Develop a model based on evidence to illustrate the relationships between systems or components of a system. (Developing and Using Models) (Personal: Initiative/Self-direction)
4. Connections to Nature of Science: Scientific Knowledge is open to revision in light of new evidence. Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.

Elaboration on the GLE:

1. Students can answer the question: How do matter and energy move through an ecosystem?
2. LS2:B Cycles of Matter and Energy Transfer in Ecosystems: Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
3. LS2:B Cycles of Matter and Energy Transfer in Ecosystems: Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
4. PS3:D Energy in Chemical Processes: The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.

Cross Cutting Concepts:

1. Systems and System 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.
2. Energy and Matter: Energy drives the cycling of matter within and between systems. Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.

Prepared Graduates:

6. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how living systems interact with the biotic and abiotic environment.

Grade Level Expectation:

6. A complex set of interactions determine how ecosystems respond to disturbances.

Evidence Outcomes

Students Can:

a. Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. (HS-LS2-6) *(Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.)*
b. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. (HS-LS2-7) *(Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. (Constructing Explanations and Designing Solutions) (Civic/Interpersonal: Civic engagement)
2. Arguments may also come from current scientific or historical episodes in science. Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (Engaging in Argument from Evidence) (Personal: Initiative/Self-direction)
3. Connections to Nature of Science: Scientific Knowledge is open to revision in light of new evidence. Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.

Elaboration on the GLE:

1. Students can answer the question: What happens to ecosystems when the environment changes?
2. LS2:C Ecosystem Dynamics, Functioning, and Resilience: Anthropogenic changes (induced by human activity) in the environment — including habitat destruction, pollution, introduction of invasive species, over-exploitation, and climate change — can disrupt an ecosystem and threaten the survival of some species.
3. LS4:D Biodiversity and Humans: Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, over-exploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

Cross Cutting Concepts:

1. Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable.

Prepared Graduates:

6. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how living systems interact with the biotic and abiotic environment.

Grade Level Expectation:

7. Organisms interact in groups to benefit the species.

Evidence Outcomes

Students Can:

a. Evaluate evidence for the role of group behavior on individual and species' chances to survive and reproduce. (HS-LS2-8) *(Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Evaluate the evidence behind currently accepted explanations to determine the merits of arguments. (Engaging in Arguments from Evidence) (Personal: Initiative/Self-direction)
2. Connections to Nature of Science: Scientific knowledge is open to revision in light of new evidence. Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.

Elaboration on the GLE:

1. Students can answer the question: How do organisms interact in groups so as to benefit individuals?
2. LS2:D Social Interactions and Group Behavior: Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.

Cross Cutting Concepts:

1. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects

Prepared Graduates:

7. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how genetic and environmental factors influence variation of organisms across generations.

Grade Level Expectation:

8. The characteristics of one generation are dependent upon the genetic information inherited from previous generations.

Evidence Outcomes

Students Can:

a. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. (HS-LS3-1) *(Clarification Statement: Does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Ask questions that arise from examining models or a theory to clarify relationships. (Asking Questions and Defining Problems) (Entrepreneurial: Inquiry/Analysis)

Elaboration on the GLE:

1. Students can answer the question: How are the characteristics of one generation related to the previous generation?
2. LS1:A Structure and Function: All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins.
3. LS3:A Inheritance of Traits: Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.

Cross Cutting Concepts:

1. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Prepared Graduates:

8. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how natural selection drives biological evolution accounting for the unity and diversity of organisms.

Grade Level Expectation:

9. Variation between individuals results from genetic and environmental factors.

Evidence Outcomes

Students Can:

a. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. (HS-LS3-3) *(Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.)*
b. Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. (HS-LS3-2) *(Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (Engaging in Argument from Evidence) (Civic/Interpersonal: Collaboration/Teamwork)
2. 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. (Analyzing and Interpreting Data) (Entrepreneurial: Critical thinking/Problem solving)
3. Connections to Nature of Science: Science is a human endeavor. Technological advances have influenced the progress of science and science has influenced advances in technology. Science and engineering are influenced by society and society is influenced by science and engineering.

Elaboration on the GLE:

1. Students can answer the question: Why do individuals of the same species vary in how they look, function, and behave?
2. LS3:B Variation of Traits: In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.

Cross Cutting Concepts:

1. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Prepared Graduates:

8. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how natural selection drives biological evolution accounting for the unity and diversity of organisms.

Grade Level Expectation:

10. Evidence of common ancestry and diversity between species can be determined by examining variations including genetic, anatomical and physiological differences.

Evidence Outcomes

Students Can:

a. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. (HS-LS4-1) *(Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Communicate scientific information (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).(Analyzing and Interpreting Data) (Entrepreneurial: Critical thinking/Problem solving)
2. Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena. A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

Elaboration on the GLE:

1. Students can answer the question: Why do individuals of the same species vary in how they look, function, and behave?
2. LS4:A Evidence of Common Ancestry and Diversity: Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.

Cross Cutting Concepts:

1. Patterns: 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.
2. Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.

Prepared Graduates:

8. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how natural selection drives biological evolution accounting for the unity and diversity of organisms.

Grade Level Expectation:

11. Genetic variation among organisms affects survival and reproduction.

Evidence Outcomes

Students Can:

a. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. (HS-LS4-2) *(Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.) (Boundary Statement: Does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.)*

b. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. (HS-LS4-3) *(Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.) (Boundary Statement: Limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. 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. (Analyzing and Interpreting Data) (Entrepreneurial: Inquiry/Analysis)
2. Construct 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. (Constructing Explanations and Designing Solutions) (Entrepreneurial: Critical thinking/Problem solving)

Elaboration on the GLE:

1. Students can answer the question: How does genetic variation among organisms affect survival and reproduction?
2. LS4:B Natural Selection: Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information — that is, trait variation — that leads to differences in performance among individuals. The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

Cross Cutting Concepts:

1. Patterns: 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.
2. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Prepared Graduates:

8. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how natural selection drives biological evolution accounting for the unity and diversity of organisms.

Grade Level Expectation:

12. The environment influences survival and reproduction of organisms over multiple generations.

Evidence Outcomes

Students Can:

a. Construct an explanation based on evidence for how natural selection leads to adaptation of populations. (HS-LS4-4) *(Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.)*

b. Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. (HS-LS4-5) *(Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Construct 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. (Constructing Explanations and Designing Solutions) (Entrepreneurial: Creativity/Innovation)
2. Arguments may also come from current or historical episodes in science. Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (Engaging in Argument from Evidence) (Entrepreneurial: Critical thinking/Problem solving)

Elaboration on the GLE:

1. Students can answer the question: How does the environment influence populations of organisms over multiple generations?
2. LS4:C Adaptation: Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. Adaptation also means that the distribution of traits in a population can change when conditions change. Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.

Cross Cutting Concepts:

1. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
2. Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.

COLORADO
Department of Education

Prepared Graduates:

8. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how natural selection drives biological evolution accounting for the unity and diversity of organisms.

Grade Level Expectation:

13. Humans have complex interactions with ecosystems and have the ability to influence biodiversity on the planet.

Evidence Outcomes

Students Can:

a. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity. (HS-LS4-6) *(Clarification Statement: Emphasis is on testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Create or revise a simulation of a phenomenon, designed device, process, or system. (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)

Elaboration on the GLE:

1. Students can answer the question: What is biodiversity, how do humans affect it, and how does it affect humans?
2. LS4:D Biodiversity and Humans: Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

Cross Cutting Concepts:

1. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Prepared Graduates:

9. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding the universe and Earth's place in it.

Grade Level Expectation:

1. All stars, including the sun, undergo stellar evolution, and the study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.

Evidence Outcomes

Students Can:

a. Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. (HS-ESS1-1) *(Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.) (Boundary Statement: Does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.)*

b. Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. (HS-ESS1-2) *(Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases [from the spectra of electromagnetic radiation from stars], which matches that predicted by the Big Bang theory [3/4 hydrogen and 1/4 helium].)*

c. Communicate scientific ideas about the way stars, over their life cycle, produce elements. (HS-ESS1-3) *(Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.) (Boundary Statement: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (Developing and Using Models) (Personal: Initiative/Self-direction)
2. Construct 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. (Constructing Explanations and Designing Solutions) (Professional: Resilience/Perseverance).
3. Communicate scientific 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.) (Obtaining, Evaluating, and Communicating Information) (Professional: Information literacy)

4. Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena. A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory.

Elaboration on the GLE:

1. Students can answer the question: What is the universe and what goes on in stars?
2. ESS1:A The Universe and Its Stars: The star called the sun is changing and will burn out over a life span of approximately 10 billion years. The sun is just one of more than 200 billion stars in the Milky Way galaxy, and the Milky Way is just one of hundreds of billions of galaxies in the universe. The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. 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, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

Cross Cutting Concepts:

1. Scale, Proportion, and Quantity: The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
2. Energy and Matter: Energy cannot be created or destroyed — only moved between one place and another place, between objects and/or fields, or between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.
3. Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Science assumes the universe is a vast single system in which basic laws are consistent.

Prepared Graduates:

9. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding the universe and Earth's place in it.

Grade Level Expectation:

2. Explanations of and predictions about the motions of orbiting objects are described by the laws of physics.

Evidence Outcomes

Students Can:

a. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. (HS-ESS1-4) *(Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.) (Boundary Statement: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Use mathematical or computational representations of phenomena to describe explanations. (Using Mathematical and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)

Elaboration on the GLE:

1. Students can answer the question: What are the predictable patterns caused by Earth's movement in the solar system?
2. ESS1:B Earth and the Solar System: Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other gradual climate changes.

Cross Cutting Concepts:

1. Scale, Proportion and Quantity: 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).

COLORADO Department of Education

Prepared Graduates:

9. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding the universe and Earth's place in it.

Grade Level Expectation:

3. The rock record resulting from tectonic and other geoscience processes as well as objects from the solar system can provide evidence of Earth's early history and the relative ages of major geologic formations.

Evidence Outcomes

Students Can:

a. Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. (HS-ESS1-5) *(Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges, a result of plate spreading, and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate, a result of past plate interactions.)*
b. Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. (HS-ESS1-6) *(Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials [obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals], the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. (Engaging in Argument from Evidence) (Personal: Initiative/Self-direction)
2. Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (Constructing Explanations and Designing Solutions) (Entrepreneurial: Creativity/Innovation)
3. Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena. A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory.

Elaboration on the GLE:

1. Students can answer the question: How do people reconstruct and date events in Earth's planetary history?
2. ESS1:C The History of Planet Earth: Continental rocks, which can be older than 4 billion years, are generally much older than rocks on the ocean floor, which are less than 200 million years old. Although active geological processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.

Cross Cutting Concepts:

1. Patterns: Empirical evidence is needed to identify patterns.
2. Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable.

Prepared Graduates:

10. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how and why Earth is constantly changing.

Grade Level Expectation:

4. Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes, and these effects occur on different time scales, from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

Evidence Outcomes

Students Can:

a. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. (HS-ESS2-1) *(Clarification Statement: Emphasis is on how the appearance of land features [such as mountains, valleys, and plateaus] and sea-floor features [such as trenches, ridges, and seamounts] are a result of both constructive forces [such as volcanism, tectonic uplift, and orogeny] and destructive mechanisms [such as weathering, mass wasting, and coastal erosion].) (Boundary Statement: Does not include memorization of the details of the formation of specific geographic features of Earth's surface.)*

b. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. (HS-ESS2-2) *(Clarification Statement: Examples should include climate feedback, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.)*

c. Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. (HS-ESS2-3) *(Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field [as constraints on convection in the outer core], and identification of the composition of Earth's layers from high-pressure laboratory experiments.)*

d. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. (HS-ESS2-4) *(Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.) (Boundary Statement: Results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Develop a model based on evidence to illustrate the relationships between systems or between components of a system. Use a model to provide mechanistic accounts of phenomena. (Developing and Using Models) (Personal: Initiative/Self-direction)
2. 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. (Analyzing and Interpreting Data) (Entrepreneurial: Critical thinking/Problem solving)
3. Connections to Nature of Science: Scientific Knowledge is Based on Empirical Evidence. Science knowledge is based on empirical evidence. Science disciplines share common rules of evidence used to evaluate explanations about natural systems. Science includes the process of coordinating patterns of evidence with current theory.

Elaboration on the GLE:

1. Students can answer the question: How do Earth's major systems interact?
2. ESS2:A Earth's Materials and Systems: Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. 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.

Cross Cutting Concepts:

1. Stability and Change: 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.
2. Energy and Matter: Energy drives the cycling of matter within and between systems.
3. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Prepared Graduates:

10. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how and why Earth is constantly changing.

Grade Level Expectation:

5. Plate tectonics can be viewed as the surface expression of mantle convection, which is driven by heat from radioactive decay within Earth's crust and mantle.

Evidence Outcomes

Students Can:

a. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. (HS-ESS2-1) *(Clarification Statement: Emphasis is on how the appearance of land features [such as mountains, valleys, and plateaus] and sea-floor features [such as trenches, ridges, and seamounts] are a result of both constructive forces [such as volcanism, tectonic uplift, and orogeny] and destructive mechanisms [such as weathering, mass wasting, and coastal erosion].) (Boundary Statement: Does not include memorization of the details of the formation of specific geographic features of Earth's surface.)*

b. Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. (HS-ESS2-3) *(Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (Developing and Using Models) (Civic/Interpersonal: Collaboration/Teamwork)

Elaboration on the GLE:

1. Students can answer the question: Why do the continents move, and what causes earthquakes and volcanoes?
2. ESS2:B Plate Tectonics and Large Scale Interactions: 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. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. 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 can be viewed as the surface expression of mantle convection.

Cross Cutting Concepts:

1. Stability and Change: Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
2. Energy and Matter: Energy drives the cycling of matter within and between systems.
3. Connections to Engineering, Technology, and Applications of Science: Interdependence of Science, Engineering, and Technology. Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.
4. Influence of Engineering, Technology, and Science on Society and the Natural World: New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Prepared Graduates:

10. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how and why Earth is constantly changing.

Grade Level Expectation:

6. The planet's dynamics are greatly influenced by water's unique chemical and physical properties.

Evidence Outcomes

Students Can:

a. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. (HS-ESS2-5) *(Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization [by testing the solubility of different materials] or melt generation (by examining how water lowers the melting temperature of most solids.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. 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), and refine the design accordingly. (Planning and Carrying Out Investigations) (Entrepreneurial: Inquiry/Analysis)

Elaboration on the GLE:

1. Students can answer the question: How do the properties and movements of water shape Earth's surface and affects its systems?
2. ESS2:C The Roles of Water in Earth's Surface Processes: The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

Cross Cutting Concepts:

1. Structure and Function: 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 its various materials.

Prepared Graduates:

10. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how and why Earth is constantly changing.

Grade Level Expectation:

7. The role of radiation from the sun and its interactions with the atmosphere, ocean, and land are the foundation for the global climate system. Global climate models are used to predict future changes, including changes influenced by human behavior and natural factors.

Evidence Outcomes

Students Can:

a. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. (HS-ESS2-2) *(Clarification Statement: Examples should include climate feedback, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.)*

b. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. (HS-ESS2-4) *(Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.) (Boundary Statement: Results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.)*

c. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. (HS-ESS2-6) *(Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere [including humans], providing the foundation for living organisms.)*

d. Construct an argument based on evidence about the simultaneous co-evolution of Earth's systems and life on Earth. (HS-ESS2-7) *(Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; 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 erosion and deposition along coastlines and provided habitats for the evolution of new life forms.) (Boundary Statement: Does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. 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. (Analyzing and Interpreting Data) (Entrepreneurial: Critical thinking/Problem solving)
2. Use a model to provide mechanistic accounts of phenomena and develop a model based on evidence to illustrate the relationships between systems or between components of a system. (Developing and Using Models) (Personal: Initiative/Self-direction)
3. Construct an oral and written argument or counter-arguments based on data and evidence. (Engaging in Argument from Evidence) (Civic/Interpersonal: Collaboration/Teamwork)
4. Connections to Nature of Science: Scientific Knowledge is Based on Empirical Evidence. Science arguments are strengthened by multiple lines of evidence supporting a single explanation.

Elaboration on the GLE:

1. Students can answer the question: What regulates weather and climate?
2. ESS2:D Weather and Climate: The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere

Cross Cutting Concepts:

1. Stability and Change: Feedback (negative or positive) can stabilize or destabilize a system. Much of science deals with constructing explanations of how things change and how they remain stable.
2. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
3. Energy and Matter: The total amount of energy and matter in closed systems is conserved.

COLORADO Department of Education

Prepared Graduates:

10. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how and why Earth is constantly changing.

Grade Level Expectation:

8. The biosphere and Earth's other systems have many interconnections that cause a continual co-evolution of Earth's surface and life on it.

Evidence Outcomes

Students Can:

a. Construct an argument based on evidence about the simultaneous co-evolution of Earth's systems and life on Earth. (HS-ESS2-7) *(Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; 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 erosion and deposition along coastlines and provided habitats for the evolution of new life forms.) (Boundary Statement: Does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Construct an oral and written argument or counter-arguments based on data and evidence. (Engaging in Argument from Evidence) (Professional: Information and Communications Technologies)

Elaboration on the GLE:

1. Students can answer the question: How do living organisms alter Earth's processes and structures?
2. ESS2:E Biogeology: The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.

Cross Cutting Concepts:

1. Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable.

Prepared Graduates:

11. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how human activities and the Earth's surface processes interact.

Grade Level Expectation:

9. Resource availability has guided the development of human society and use of natural resources has associated costs, risks, and benefits.

Evidence Outcomes

Students Can:

a. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. (HS-ESS3-1) *(Clarification Statement: Examples of key natural resources include access to fresh water [such as rivers, lakes, and groundwater], regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes [such as volcanic eruptions and earthquakes], surface processes [such as tsunamis, mass wasting, and soil erosion], and severe weather [such as hurricanes, floods, and droughts]. Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.)*

b. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. (HS-ESS3-2) *(Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources [such as minerals and metals] where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining [for coal, tar sands, and oil shales] and pumping [for petroleum and natural gas]. Science knowledge indicates what can happen in natural systems — not what should happen.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Construct 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. (Constructing Explanations and Designing Solutions) (Civic/Interpersonal: Civic engagement)
2. Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations). (Engaging in Argument from Evidence) (Personal: Initiative/Self-direction)

Elaboration on the GLE:

1. Students can answer the question: How do humans depend on Earth's resources?
2. ESS3:A Natural Resources: Resource availability has guided the development of human society. All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

Cross Cutting Concepts:

1. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
2. Connections to Nature of Science: Science Addresses Questions About the Natural and Material World. Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

Prepared Graduates:

11. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how human activities and the Earth's surface processes interact.

Grade Level Expectation:

10. Natural hazards and other geological events have shaped the course of human history at local, regional, and global scales.

Evidence Outcomes

Students Can:

a. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. (HS-ESS3-1) *(Clarification Statement: Examples of key natural resources include access to fresh water [such as rivers, lakes, and groundwater], regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes [such as volcanic eruptions and earthquakes], surface processes [such as tsunamis, mass wasting, and soil erosion], and severe weather [such as hurricanes, floods, and droughts]. Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Construct 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. (Constructing Explanations and Designing Solutions) (Entrepreneurial: Critical thinking/Problem solving)

Elaboration on the GLE:

1. Students can answer the question: How do natural hazards affect individuals and societies?
2. ESS3:B Natural Hazards: Natural hazards and other geologic events have shaped the course of human history, and have significantly altered the sizes of human populations and have driven human migrations.

Cross Cutting Concepts:

1. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Prepared Graduates:

11. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how human activities and the Earth's surface processes interact.

Grade Level Expectation:

11. Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources, including the development of technologies.

Evidence Outcomes

Students Can:

a. Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity. (HS-ESS3-3) *(Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.) (Boundary Statement: Computational simulation is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.)*
b. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. (HS-ESS3-4) *(Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use [such as for urban development, agriculture, and livestock, or surface mining]. Examples for limiting future impacts could range from local efforts [such as reducing, reusing, and recycling resources] to large-scale geoengineering design solutions [such as altering global temperatures by making large changes to the atmosphere or ocean].)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Create a computational model or simulation of a phenomenon, designed device, process, or system. (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)
2. Design 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. (Constructing Explanations and Designing Solutions) (Civic/Interpersonal: Global/Cultural awareness)

Elaboration on the GLE:

1. Students can answer the question: How do humans change the planet?
2. ESS3:C Human Impacts on Earth's Systems: 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 preclude ecosystem degradation.

Cross Cutting Concepts:

1. Stability and Change: 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.
2. Connections to Nature of Science: Science is a Human Endeavor. Science is a result of human endeavors, imagination, and creativity.

Prepared Graduates:

11. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how human activities and the Earth's surface processes interact.

Grade Level Expectation:

12. Global climate models used to predict future climate change continue to improve our understanding of the impact of human activities on the global climate system.

Evidence Outcomes

Students Can:

a. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems. (HS-ESS3-5) *(Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes [such as precipitation and temperature] and their associated impacts [such as on sea level, glacial ice volumes, or atmosphere and ocean composition].) (Boundary Statement: Limited to one example of a climate change and its associated impacts.)*
b. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. (HS-ESS3-6) *(Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.) (Boundary Statement: Does not include running computational representations but is limited to using the published results of scientific computational models.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Analyze data using computational models in order to make valid and reliable scientific claims. (Analyzing and Interpreting Data) (Entrepreneurial: Critical thinking/Problem solving)
2. Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (Using Mathematics and Computational Thinking) (Professional: Information and Communications Technologies)
3. Connections to Nature of Science: Scientific Investigations Use a Variety of Methods. Science investigations use diverse methods and do not always use the same set of procedures to obtain data. New technologies advance scientific knowledge.
4. Scientific Knowledge is Based on Empirical Evidence: Science arguments are strengthened by multiple lines of evidence supporting a single explanation.

Elaboration on the GLE:

1. Students can answer the question: How do people model and predict the effects of human activities on Earth's climate?
2. ESS3:D Global Climate Change: Though the magnitudes of humans' impacts are greater than they have ever been, so too are humans' abilities to model, predict, and manage current and future impacts. Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities, as well as to changes in human activities.

Cross Cutting Concepts:

1. Stability and Change: Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
2. Systems and System Models: 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.