SOUTH CAROLINA
DEPARTMENT OF EDUCATION

Earth and Space Science Performance Targets

for the
South Carolina College- and Career-Ready Science Standards 2021

For use 2025-2026

July 2025

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State Superintendent of Education

Contents

Purpose and Use

Science is a way of understanding the physical universe using observation and experimentation to explain natural phenomena. Science also refers to an organized body of knowledge that includes core ideas to the disciplines and common themes that bridge the disciplines. As science educators we must take a 3-dimensional approach in facilitating student learning. By addressing content, science and engineering practices and crosscutting concepts, students can have relevant and evidence-based instruction that can help solve current and future problems.

This document is intended as a guide for discerning and describing features of students and their work who have met the stated Performance Expectation (PE). This document is not intended to be read from cover to cover, but to be used, when needed, to support teacher professional learning and curriculum decisions. This is not intended for student use, and thus is not written in student-friendly language. This is not a curriculum or a means to limit instruction in the classroom. Although each PE states a dedicated Science and Engineering Practice (SEP) and Crosscutting Concept (CCC), students will need to use the whole range of SEPs and CCCs to achieve success by the end of instruction.

Three-dimensional science learning requires discipline specific communication skills. This means that effective science learning occurs when students are expected to speak, listen, read, and write in ways that are appropriate to science. With each Performance Target, there are question/sentence stems and terminology to support student discourse about phenomena to help teachers facilitate the acquisition of science discourse. Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding. The terms and stems in this section are intended to provide a baseline for teachers, neither list is exhaustive nor complete.

In addition to the doing (SEP), thinking (CCC), and learning of science knowledge (Disciplinary Core Ideas) outlined here, students will also require a working knowledge of grade-level appropriate tools and techniques of science. Students should know and recognize how scientists and engineers use these tools and techniques, not just identify them. Students should be able to use these tools to gather data, describe how these tools gather data, and/or interpret data sampled from them. Students will need to understand and apply the conventions of scientific notation when working with extremely large or small quantities of measurement and their calculations.

Document Updates

July 2025

- All Performance Expectation statements have been reformatted to call out each of the dimensions as follows:
  - Science and Engineering Practice – **bold**
  - Crosscutting Concept – *italicize*
  - Disciplinary Core Idea – regular
- The watermark from previous versions of this resource has been replaced with the wording “For use 2025-2026” on the title page and in the footer. This change was made to improve accessibility of this resource.
- Because scientific notation is no longer an expectation of the math standards, the following statement was added to the purpose and use page to support the teaching and understanding of scientific notation: “Students will need to understand and apply the conventions of scientific notation when working with extremely large or small quantities of measurement and their calculations.”

June 2024

- Updated watermark to 2024-2025.
- Adjusted formatting and grammar.

ESS1 – Earth’s Place in the Universe

E-ESS1-1. Develop a model based on evidence to illustrate that energy generated by nuclear fusion within the sun (and other stars) *radiates to and influences orbiting planets*.

> ***Clarification Statement:*** Emphasis should be on the energy from nuclear fusion in a star’s core (relative to the star’s mass and age) radiating to nearby planets as seen in the Earth-Sun system. This energy varies in cyclic and non-cyclic ways over the lifespan of the star. Examples of evidence could include observations of other solar systems, surface fluctuations, electromagnetic radiation emissions, atmospheric interactions, solar incidence, and albedo.
> ***State Assessment Boundary:*** Assessment does not include details of the mechanism of nuclear fusion. Assessment does not include details of the atomic and subatomic processes involved with the sun’s nuclear fusion.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Developing and Using Models Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Develop a model (including mathematical and computational) to generate data to support explanations, predict phenomena, and analyze systems.	**ESS1.A: The Universe and Its Stars** Nuclear fusion within stars releases electromagnetic energy (seen as starlight). Stars go through a sequence of developmental stages over their lifespans-- they are formed; evolve in size, mass, and brightness; and eventually burn out. The Sun is a medium sized star that is about halfway through its predicted 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. **PS3.D: Energy in Chemical Processes and Everyday Life** Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (*secondary*)	**Energy and Matter** Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Observable features of student performance by the end of the course:

1. **Components of the model**
    a. Students develop/use a model and identify relevant components, including:
        i. hydrogen as the Sun's (and other stars') fuel,
        ii. helium and energy (photons) as the products of fusion processes in the Sun (and other stars),
        iii. solar energy (for example: visible light, ultraviolet light, gamma rays, etc.), and
        iv. orbiting planets.
2. **Relationships**
    a. Students develop/use a model and describe relationships among the components, including:
        i. the fusion of hydrogen in the Sun (and other stars) core to produce helium and energy (photons),
        ii. the release of solar energy from the surface of the Sun, and
        iii. that released solar energy influences orbiting planets.
3. **Connections**
    a. Students develop/use a model to predict how the relative proportions of hydrogen and helium change as the Sun ages.
    b. Students develop/use a model to describe the scale of energy released by the fusion process as being much larger than the energy released by chemical processes.
    c. Students develop/use a model to describe the influence of solar energy (for example: visible light, ultraviolet light, gamma rays, etc.), on orbiting planets.

E-ESS1-1 Academic Language

Question/Sentence Stems

- One evidence we have for the cycling of matter in this system is _______.
- The flow/transfer of energy causes _______ to occur in the system.
- Energy transfer mechanisms include _______.
- When energy leaves the system, the energy _______.
- During fusion, the matter in the system is _____ and the energy in the system _____.
- The (varying) mass of stars exemplifies how matter _______ and how energy _______ through the system.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- albedo
- atmosphere
- atomic nuclei
- convection
- core
- electromagnetic radiation
- energy
- fission
- gamma ray
- heavy elements
- helium
- hydrogen
- infrared (IR) radiation
- Law of Conservation of Energy
- Law of Conservation of Mass
- luminosity
- mass
- neutron
- nuclear fusion
- nucleosynthesis
- nucleus
- photon
- proton
- radiation
- solar flare
- solar maximum
- solar minimum
- solar storm
- star life cycle
- subatomic particle
- sunspot
- sunspot cycle
- ultraviolet (UV) radiation
- ultraviolet light
- visible light

E-ESS1-2. Construct an explanation of the Big Bang Theory based on evidence to show that the universe is *changing over time*.

Clarification Statement: Emphasis is on astronomical evidence that shows the expansion, cooling, and observed composition of the universe. Examples of supporting data include red shift of light from receding galaxies, cosmic microwave background radiation, and spectra of electromagnetic radiation from stars and interstellar gases that match predictions from models of the Big Bang theory.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including [models, peer review, simulations, theories, students' own investigations]) 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.	**ESS1.A: The Universe and Its Stars** 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. Stars' radiation of visible light and other forms of energy can be measured and studied to develop explanations about the formation, age, and composition of 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. **PS4.B: Electromagnetic Radiation** Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. (*secondary*) **ETS2.A: 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. (*secondary*)	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.

Observable features of student performance by the end of the course:

1. **Articulating the explanations of phenomena**
    a. Students articulate a statement describing/explaining that astronomical evidence from multiple sources is used collectively to support the Big Bang theory and that the universe continues to change over time.
2. **Evidence**
    a. Students identify and describe the evidence to construct the explanation, including:
        i. the composition (hydrogen, helium, and heavier elements) of stars,
        ii. the hydrogen-helium ratio of stars and interstellar gases,
        iii. the redshift of the majority of galaxies and the redshift vs. distance relationship, and
        iv. the existence of cosmic background radiation.
3. **Reasoning**
    a. Students use the following chain of reasoning to connect the evidence and support, refute, or revise an explanation, including:
        i. Redshifts indicate that an object is moving away from the observer, thus the observed redshift for most galaxies and the redshift vs. distance relationship is evidence that the universe is expanding.
        ii. The observed cosmic background radiation and the ratio of hydrogen to helium have been shown to be consistent with a universe that was very dense and hot a long time ago and evolved through different stages as it expanded and cooled.
        iii. An expanding universe must have been smaller in the past and can be extrapolated back in time to a tiny size from which it expanded.

E-ESS1-2 Academic Language

Question/Sentence Stems

- The things that stay the same are _______.
- The things that change are _______.
- The things that are changing slowly/quickly in this system are _______.
- The _______(event) changed this system by _______.
- _______ was affected by the change of _______.
- _______ are causing this system to be unstable.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- absolute magnitude
- absorption
- apparent magnitude
- Big Bang Theory
- blueshift
- cosmic microwave background radiation
- Doppler effect
- electromagnetic radiation
- element
- emission
- expanding universe
- fission
- frequency
- fusion
- galaxy
- galaxy cluster
- helium
- Hubble's Law
- hydrogen
- Law of Conservation of Mass
- light-year
- non-stellar gases
- parallax
- recessional velocity
- redshift
- reflection
- refraction
- spectra
- spectroscope
- spectrum
- star
- telescope
- visible light
- wavelength

E-ESS1-3. Construct an explanation using evidence to explain *the ways elements are produced over* the life cycle of a star.

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. Emphasis is on the concept that the matter found in our solar system originated from the deaths of other stars. Examples of evidence include data from stars such as composition, temperature, size, mass, and luminosity.
State Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with nucleosynthesis.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including [models, peer review, simulations, theories, students' own investigations]) 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.	**ESS1.A: The Universe and Its Stars** The study of stars' light spectra and brightness is used to identify compositional elements of stars. Stars go through a sequence of developmental stages--they are formed; evolve in size, mass, and brightness; and eventually burn out. 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. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. Material from earlier stars that explode as supernovas is recycled to form younger stars and their planetary systems.	**Energy and Matter** Energy and matter cannot be created nor destroyed - only moved between one place and another place between objects and/or fields, or between systems.

Observable features of student performance by the end of the course:

1. **Articulating the explanations of phenomena**
    a. Students articulate a statement describing/explaining relationships between:
        i. the life cycle of the stars,
        ii. the production of elements,
        iii. the conservation of the number of protons plus neutrons in stars, and
        iv. that atoms are not conserved in nuclear fusion, but the total number of protons plus neutrons is conserved.
2. **Evidence**
    a. Students identify and describe the evidence to construct the explanation, including:
        i. helium and a small amount of other light nuclei (up to lithium) were formed from high-energy collisions from protons and neutrons,
        ii. more massive elements, up to iron, are produced in the cores of stars by a chain of nuclear fusion,
        iii. supernova explosions of massive stars produce elements more massive than iron,
        iv. correlation between a star's mass and stage of development and the types of elements it can create during its lifetime, and
        v. electromagnetic emission and absorption spectra are used to determine a star's composition, motion, temperature, size, mass, luminosity, and distance to Earth.
3. **Reasoning**
    a. Students use the following chain of reasoning to connect the evidence and support, refute, or revise an explanation, including:
        i. Helium and a small amount of other light nuclei (up to lithium) were formed from high-energy collisions from protons and neutrons in the early universe before any stars existed.
        ii. More massive elements, up to iron, are produced in the cores of stars by a chain of nuclear fusion, which also releases energy.
        iii. Supernova explosions of massive stars produce elements more massive than iron.
        iv. There is a correlation between a star's mass and stage of development and the types of elements it can create during its lifetime.
        v. Electromagnetic emission and absorption spectra are used to determine a star's composition, motion, temperature, size, mass, luminosity, and distance to Earth.

E-ESS1-3 Academic Language

Question/Sentence Stems

- The light from distant stars tells us _______.
- The composition of matter in the Universe tells us _______.
- In this system, energy impacts matter when _______.
- During the Big Bang, the matter in the system is _______.
- After the Big Bang, the matter in the system is _______.
- Using evidence of cosmic background radiation (energy/heat), we can infer _______.
- Using evidence of redshift/blueshift of matter (galaxies) (or spectral lines), we can infer _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- absolute magnitude
- absorption lines
- absorption spectrum
- apparent magnitude
- Big Bang Theory
- black hole
- blue giant
- burnout
- electromagnetic radiation
- elements
- emission lines
- emissions spectrum
- endothermic reaction
- exothermic reaction
- fission
- fusion
- gamma rays
- globular cluster
- gravity
- heavy elements
- H-R diagram
- Law of Conservation of Energy
- Law of Conservation of Mass
- light-year
- luminosity
- main sequence
- mass
- nebulae
- neutrinos
- neutron
- nova
- nuclear reactions
- nucleons
- nucleosynthesis
- planetary nebula
- pressure
- proton
- protostar
- red giant
- stability
- star life cycle
- supergiant
- supernova
- supernova remnant
- surface temperature
- telescope
- visible light
- white dwarf

E-ESS1-4. Use mathematical or computational representations *to predict* the motion of orbiting objects in the universe due to gravity.

> ***Clarification Statement:*** Emphasis is on predicting orbital motion of naturally occurring or human-made objects using Kepler's laws and Newton's law of gravity.
> ***State Assessment Boundary:*** 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.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use mathematical, computational, and/or algorithmic representations of phenomena to describe and/or support claims and/or explanations.	**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. **ETS2.A: 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. (*secondary*)	**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).

Observable features of student performance by the end of the course:

1. **Representation**
   a. Students develop/use mathematical and/or computational models of orbital motion to identify and describe relevant components, including:
      i. the trajectories of orbiting bodies (for example: planets, moons, human-made spacecraft, etc.) and
      ii. a revolving body's eccentricity ($e = \frac{c}{a}$; where f is the distance between foci of an ellipse and d is the ellipse's major axis length [Kepler's first law of planetary motion]).
2. **Mathematical and/or computational modeling**
   a. Students develop/use mathematical and/or computational models of orbital motion to model that the square of a revolving body's period is proportional to the cube of its distance to a gravitational center ($T^2 \propto R^3$; where T is the orbital period and R is the semi-major axis of the orbit [Kepler's third law of planetary motion]).
3. **Analysis**
   a. Students develop/use and analyze a mathematical and/or computational model of Kepler's second law of planetary motion (an orbiting body sweeps out equal areas in equal time) to predict the relationship between:
      i. the distance between an orbiting body and its star, and
      ii. the object's orbital velocity (for example: the closer an orbiting body is to a star, the larger its orbital velocity will be).

E-ESS1-4 Academic Language

Question/Sentence Stems

- To understand the phenomenon of _______, I/we can use a scale of _______ in my/our model because _______.
- Different temporal scales include _______. This is important to my model because _______.
- Different spatial scales include _______. This is important to my model because _______.
- Using different temporal and spatial scales allows for _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- aphelion
- astronomical unit
- eccentricity ($e = \frac{c}{a}$)
- ellipse
- foci
- focus
- gravitation
- gravitational constant
- orbit
- perihelion
- period
- revolution
- rotation
- satellite
- semi-major axis
- semi-minor axis
- Kepler's Laws
- axis
- trajectory
- velocity ($v = \frac{\Delta x}{\Delta t}$)
- speed ($s = \frac{d}{t}$)

E-ESS1-5. 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.

> ***Clarification Statement:*** Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages of 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).

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Engaging in Argument from Evidence Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.	**ESS1.C: The History of Planet Earth** Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. Tectonic processes continually generate new ocean seafloor at ridges and destroy old seafloor at trenches. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** The theory of plate tectonics is supported by evidence of ocean floor spreading over time given by tracking magnetic patterns in undersea rocks and coordinating them with changes to Earth's magnetic axis data. Earth's history is still being written. Continents are continually being shaped and reshaped by competing constructive and destructive geological processes. North America, for example, has gradually grown in size over the past 4 billion years through a complex set of interactions with other continents, including the addition of many new crustal segments.	**Patterns** Empirical evidence is needed to identify patterns.

Observable features of student performance by the end of the course:

1. **Identifying the explanation and supporting evidence**
    a. Students identify an explanation about how the crustal materials of different ages are arranged on Earth's surface in a pattern that can be attributed to
        i. plate tectonic activity and
        ii. formation of new rock from magma rising where plates are moving apart.
2. **Identifying additional evidence relevant to the evaluation**
    a. Students identify and describe additional evidence (for example: data, information, models, etc.) that was not provided but is relevant to the explanation and its evaluation, including:
        i. measurement of the ratio of parent to daughter atoms produced during radioactive decay to determine the ages of rocks,
        ii. ages and locations of continental rocks,
        iii. ages and locations of rocks found on opposite sides of mid-ocean ridges, and
        iv. type and location of plate boundaries relative to the type, age, and location of crustal rocks.
3. **Evaluating and critiquing**
    a. Students evaluate how the evidence supports or refutes the explanation about the ages of crustal rocks, including:
        i. continental crust being older than oceanic crust,
        ii. the oldest continental rocks are located at the center of continents and decrease in age with proximity to mid-ocean ridges, and
        iii. the oldest oceanic crust is nearest the continents and decrease in age with proximity to mid-ocean ridges.
    b. Students synthesize the evidence to describe the relationship between the motion of continental plates and the ages of crustal rocks, including that:
        i. At boundaries where plates are moving apart (for example: mid-ocean ridges), material from the interior of Earth must be emerging and forming new rocks with the youngest ages.
        ii. Regions furthest from plate boundaries (continental centers) have the oldest rocks because new crust is added to the edge of continents at places where plates are coming together (for example: subduction zones).
        iii. The oldest crustal rocks are found on the continents because oceanic crust is constantly being destroyed at places where plates are coming together (for example: subduction zones).

E-ESS1-5 Academic Language

Question/Sentence Stems

- The interactions of plates at boundaries causes _______.
- _______ are the features associated with a convergent plate boundary.
- _______ are the features associated with a divergent plate boundary.
- _______ are the features associated with a transform plate boundary.
- _______ are the features associated with hotspots.
- The movement of tectonic plates causes ______ because _______.
- The movement of tectonic plates can be proved by ______ because _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- asthenosphere
- basalt
- constructive
- continental drift theory
- continental plate
- convection
- convergence
- convergent plate boundary
- core
- crust
- daughter atom
- destructive
- divergence
- divergent plate boundary
- earthquake pattern
- geologic process
- igneous
- lava
- lithosphere
- magma
- magnetic axis
- magnetic field
- magnetic polarity
- magnetic strips
- magnetometer
- mantle
- metamorphic
- mid ocean ridge
- ocean basin
- oceanic plate
- paleomagnetism
- parent atom
- plate boundary
- plate tectonics
- radioactive decay
- regional hotspot
- reversals
- rift valley
- rock cycle
- satellite
- seafloor spreading
- sedimentary
- sonar
- subduction
- subduction zone
- time scale
- trench
- volcanic

E-ESS1-6. 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.

> ***Clarification Statement:*** Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed simultaneously along with the rest of the solar system. 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.

Science and Engineering Practices	Disciplinary Core Ideas	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.	**ESS1.B: The Earth and the Solar System** The solar system consists of the Sun and a collection of objects of varying sizes and conditions. This system appears to have formed from a disk of dust and gas, drawn together by gravity approximately 4.6 billion years ago. **ESS1.C: The History of Planet Earth** Radioactive decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geological time. Although active geologic 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. Study of other planets and their moons, many of which exhibit features such as volcanism and meteor impacts similar to those found on Earth, also help illuminate aspects of Earth's history and changes. **PS1.C: Nuclear Processes** Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials thereby fixing the scale of geological time. (*secondary*)	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.

Observable features of student performance by the end of the course:

1. **Articulating the explanation of phenomena**
    a. Students articulate a statement describing/explaining Earth's formation and early history, including:
        i. Earth formed along with the rest of the solar system 4.6 billion years ago.
        ii. Early Earth was bombarded just like other objects in the solar system were bombarded.
        iii. Erosion and plate tectonics on Earth have destroyed much of the evidence of this bombardment, thus the relative scarcity of impact craters on Earth.
2. **Evidence**
    a. Students identify and describe the evidence to construct the explanation, including:
        i. age and composition of Earth's oldest rocks, lunar rocks, and meteorites as determined by radiometric dating,
        ii. composition of solar system objects,
        iii. observations of the size and distribution of impact craters on the surface of Earth and other solar system objects (for example: the Moon, Mercury, Mars, etc.), and
        iv. activity of plate tectonic processes, such as volcanism, and surface processes, such as erosion, on Earth.
3. **Reasoning**
    a. Students use the following chain of reasoning to connect the evidence and support, refute, or revise an explanation, including:
        i. The radiometric ages of lunar rocks, meteorites, and the oldest Earth rocks provide evidence for an origin of the solar system 4.6 billion years ago, with the creation of a solid Earth crust about 4.4 billion years ago.
        ii. Other planetary surfaces and their patterns of impact cratering can be used to infer that Earth had many impact craters early in its history.
        iii. The relative lack of impact craters and the age of most rocks on Earth compared to other bodies in the solar system can be attributed to processes like volcanism, plate tectonics, and erosion that have reshaped Earth's surface, and that is why most of Earth's rocks are much younger than Earth itself.

E-ESS1-6 Academic Language

Question/Sentence Stems

- The data shows that _______ changes over time.
- _______ supports the idea that _______ has changed over geologic time.
- The components that are changing slowly/quickly in this system are _______.
- The _______(event) changed this system by _______.
- _______ was affected by the change of _______.
- _______ are causing/caused this system to be unstable.
- Evidence for Earth's formation includes _______.
- Evidence for changes to Earth's systems since its formation includes _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- absolute age
- accretion
- ancient core
- asteroid
- asthenosphere
- bedrock
- billion
- Cambrian
- continental crust
- convection current
- crater
- cycle
- erosion
- exponential
- geologic time
- gravitational collapse
- gravity
- half-life
- inner core
- isotope
- lithosphere
- mantle
- mass extinction
- meteor
- meteorite
- mineral
- nuclear
- ocean ridge
- ocean trench
- oceanic crust
- particulates
- planetary surfaces
- planetesimals
- plate tectonics
- Precambrian
- primordial atmosphere
- radioactive decay
- radiometric dating
- relative age
- rock record
- seafloor spreading
- sedimentation
- solar nebula
- volcanism

ESS2 – Earth's Systems

E-ESS2-1. Use evidence to argue how Earth's internal and external processes operate *to form and modify* continental and ocean-floor features throughout Earth's history.

> ***Clarification Statement:*** Emphasis is on the core idea that convection leads to the creation and destruction of surface features. Plate movements and many crustal features and events are a result of this phenomenon, but there are other surface processes, which shape Earth's surface as well. The appearance of land features (such as mountains, valleys, coastlines, 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). Examples include seafloor spreading at ridges (evidenced by paleomagnetic data and radiometric dating of rocks), subduction at trenches (evidenced by seismic data and volcanoes), and weathering and erosion among mountains (evidenced by weathering, erosion, and deposition patterns of streams).
>
> ***State Assessment Boundary:*** Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Engaging in Argument from Evidence Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. Construct an oral and written argument or counter- arguments based on data and evidence.	**ESS2.A: Earth Materials and Systems** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. A deep knowledge of how feedback works within and among Earth's systems is still lacking, thus limiting scientists' ability to predict some changes and their impacts. The top part of the mantle, along with the crust, forms structures known as tectonic plates. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to long-term tectonic cycles. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** 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. The plates move across Earth's surface, carrying the continents, creating and destroying ocean basins, producing earthquakes and volcanoes, and forming mountain ranges and plateaus. Most continental and ocean floor features are the result of geological activity and earthquakes along plate boundaries. The exact patterns depend on whether the plates are being pushed together to create mountains or deep ocean trenches, being pulled apart to form new ocean floor at mid-ocean ridges, or sliding past each other along surface faults.	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.

Observable features of student performance by the end of the course:

1. **Developing a claim**
    a. Students make a claim that Earth's internal and external processes form and modify different continental and ocean-floor features throughout Earth's history.
2. **Identifying scientific evidence**
    a. Students identify and describe the evidence that supports the claim, including:
        i. descriptions and locations of specific continental and ocean-floor features,
        ii. internal processes (for example: volcanism, uplift, etc.) and surface processes (for example: weathering, erosion, etc.), and
        iii. temporal data about the relative times over which processes act to produce continental and/or ocean-floor features.
3. **Evaluating and critiquing evidence**
    a. Students identify strengths and weaknesses of the evidence to support the claim, including:
        i. types of sources,
        ii. sufficiency, including validity and reliability, of the evidence to make and defend the claim, and/or
        iii. any alternative interpretations of the evidence and why the evidence supports or does not support the student's claim, as opposed to any other claims.
4. **Reasoning and synthesis**
    a. Students use the following chain of reasoning to connect the evidence:
        i. Specific internal processes (for example: volcanism, mountain building, uplift, etc.) are identified as causal agents in building up Earth's surface over time.
        ii. Specific surface processes (for example: weathering, erosion, etc.) are identified as causal agents in wearing down Earth's surface over time.
        iii. Interactions and feedback between processes are identified (for example: mountain-building changes weather patterns that then change the rate of erosion of mountains).
        iv. The rate at which a feature changes is related to the time scale on which the processes operate. Features can form or change slowly due to processes that act on long time scales (for example: continental positions due to plate drift) or rapidly due to processes that act on short time scales (for example: volcanic eruptions).

E-ESS2-1 Academic Language

Question/Sentence Stems

- The things that stay the same are _______.
- The things that change are _______.
- The things that are changing slowly/quickly in this system are _______.
- The _______(event) changed this system by _______.
- _______ was affected by the change of _______.
- _______ are causing this system to be unstable.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- coastal erosion
- constructive forces
- continental boundary
- continental crust
- convection
- convergent plate boundary
- crustal deformation
- crustal plate movement
- density
- deposition
- destructive forces
- divergent plate boundary
- Earth's magnetic field
- earthquake
- electromagnetic radiation
- energy
- erosion
- fault
- feedback effect
- geochemical reaction
- geologic activity
- heat
- inner core
- irreversible
- isotope
- mantle
- mass wasting
- mountain
- nuclear
- ocean basin
- ocean ridge
- ocean trench
- oceanic crust
- orogeny
- outer core
- paleomagnetic data
- plate tectonics
- plateau
- pressure
- radioactive decay
- radiometric dating
- recrystallization
- rock composition
- seafloor spreading
- seamount
- seismic waves
- slab drag
- sonar
- stream
- subduction
- tectonic uplift
- thermal convection
- time scale
- transform plate boundary
- trench
- unstable atomic nucleus
- uplift
- valley
- volcanism
- weathering

E-ESS2-2. Analyze data to make the claim that one change to Earth's surface *can create feedbacks* that cause changes to other Earth systems.

> ***Clarification Statement:*** Examples should include climate feedback, such as how an increase in greenhouse gases causes a rise in global temperatures that melt 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.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Analyzing and Interpreting Data Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. 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.	**ESS2.A: Earth Materials and Systems** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. Transfers of energy and the movements of matter can cause chemical and physical changes among Earth's materials and living organisms. **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. **ETS2.B: 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. (*secondary*)	**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.

Observable features of student performance by the end of the course:

1. **Organizing data**
    a. Students organize data that represent measurements of changes in hydrosphere, cryosphere, atmosphere, biosphere, or geosphere in response to a change in Earth's surface.
2. **Identifying relationships**
    a. Students analyze data to determine the relationship between:
        i. changes in one system and changes in another (or within the same) Earth system and
        ii. possible feedbacks, including one example of feedback to the climate.
    b. Students analyze data to identify effects of human activity and specific technologies on Earth's systems.
3. **Interpreting data**
    a. Students use the analyzed data to describe a mechanism for the feedbacks between two of Earth's systems and whether the feedback is positive or negative, increasing (destabilizing) or decreasing (stabilizing) the original changes.
    b. Students use the analyzed data to describe an unanticipated or unintended effect of a selected technology on Earth's systems.

E-ESS2-2 Academic Language

Question/Sentence Stems

- The things that stay the same are _______.
- The things that change are _______.
- The things that are changing slowly/quickly in this system are _______.
- The _______(event) changed this system by _______.
- _______ was affected by the change of _______.
- _______ are causing this system to be unstable.
- _______ is an example of positive feedback.
- _______ is an example of negative feedback.
- _______ (increased/decreased) albedo will result in ______ (increased/decreased) temperature, which in term will result in _______ (increased/decreased) albedo. This is an example of a _______ (positive/negative) feedback.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- absorption
- acidification
- albedo
- anthropogenic changes
- atmosphere
- atmospheric circulation
- atmospheric composition
- biosphere
- carbon cycle
- chemical change
- climate change
- coastal erosion
- convection cycle
- cryosphere
- destabilizing
- electromagnetic radiation
- energy
- feedback effect
- geoscience
- geosphere
- glacier
- greenhouse gas
- ground vegetation
- groundwater recharge
- hydrosphere
- mean surface temperature
- methane
- negative feedback loop
- ocean circulation
- physical change
- positive feedback loop
- redistribution
- reflection
- re-radiation
- runoff
- sea level
- sediment transport
- soil erosion
- solar energy
- stabilizing
- technology

E-ESS2-3. Develop a model based on evidence of Earth's interior **that describes** *cycling of matter* through convection processes.

> ***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), volcanoes, and identification of the composition of Earth's layers from high-pressure laboratory experiments.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Develop a model based on evidence to illustrate and/or predict the relationships between systems or between components.	**ESS2.A: Earth Materials and Systems** 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. All of Earth's processes are the result of energy flowing and matter cycling within and among Earth systems. 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 the gravitational movement of denser materials toward the interior. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** 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. The top part of the mantle, along with the crust, make up the moving tectonic plates of the lithosphere. Tectonic plates ride above giant convection cells that bring matter from the hot inner mantle up to the cool surface. The plates move across Earth's surface, carrying the continents, creating and destroying ocean basins, producing earthquakes and volcanoes, and forming mountain ranges and plateaus. **PS4.A: Wave Properties** Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (*secondary*) **ETS2.A: 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. (*secondary*)	**Energy and Matter** Energy and matter cannot be created nor destroyed - only moved between one place and another place between objects and/or fields, or between systems. The total amount of energy and matter in closed systems is conserved.

Observable features of student performance by the end of the course:

1. **Components of the model**
   a. Students develop/use a model (for example: graphical, verbal, mathematical, etc.) and identify the relevant components based on seismic and magnetic evidence (for example: pattern of the geothermal gradient or heat flow measurements) from Earth's interior, including:
      i. Earth's interior in cross-section and radial layers (crust, mantle, liquid outer core, solid inner core) determined by density,
      ii. plate activity in the outer part of the geosphere,
      iii. radioactive decay and residual thermal energy from the formation of Earth as an energy source,
      iv. heat loss at the surface of Earth, and
      v. convection processes that cause hot matter to rise (move away from the center) and cool matter to fall (move toward the center).
2. **Relationships**
   a. Students develop/use a model to describe the relationships between components, including:
      i. Energy released by radioactive decay in Earth's crust and mantle and residual thermal energy from Earth's formation provide energy that drives the flow of matter in the mantle.
      ii. Thermal energy is released at the surface of the Earth as new crust is formed and cooled.
      iii. The flow of matter by convection in the solid mantel and the sinking of cold, dense crust back into the mantel exert forces on crustal plates that then move, producing tectonic activity.
      iv. The flow of matter by convection in the liquid outer core generates the Earth's magnetic field.
      v. Matter is cycled between the crust and the mantle at plate boundaries. Where plates are pushed together, cold crustal material sinks back into the mantle, and where plates are pulled apart, mantle materials can be integrated into the crust, forming new rock.
3. **Connections**
   a. Students develop/use a model to describe the cycling of matter by thermal convection in Earth's interior, including:
      i. the flow of matter in the mantle that causes crustal plates to move,
      ii. the flow of matter in the liquid outer core that generates the Earth's magnetic field, including evidence of polar reversals,
      iii. the radial layers determined by density in Earth's interior, and
      iv. the addition of thermal energy released by radioactive decay in Earth's crust and mantle.

E-ESS2-3 Academic Language

Question/Sentence Stems

- In Earth's interior, matter is cycled by _______.
- The energy for _______ is from _______.
- The flow of energy causes _______ to occur in the system.
- The energy is entering the system by _______.
- In the system, the cycling of matter _______.
- The flow of energy causes _______ to occur in the system as seen with _______ as evidence from the investigation.
- The flow of energy between _______ and _______ drives the changes to the system as seen by _______ because _______.
- My/Our diagram shows the flow energy in _____ as seen by _______ because _______.
- The effect of changing temperature on density is _______.
- The pattern of density of Earth's interior layers is _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- chemical process
- composition
- continental crust
- convection
- convection cell
- crustal movement
- cycling of matter
- density
- Earth's elements
- Earth's internal energy sources
- earthquake
- geochemical cycle
- geochemical reaction
- geoscience
- geosphere
- heat loss
- inner core
- interface
- isotope
- lithosphere
- magnetic field
- mantle
- molten rock
- mountain range
- ocean basin
- oceanic crust
- outer core
- physical process
- plate tectonics
- plateau
- polar reversal
- pressure
- radial layers
- radioactive decay
- reflection
- residual thermal energy
- seismic wave
- slab drag
- tectonic uplift
- thermal convection
- time scale
- unstable atomic nucleus
- volcano

E-ESS2-4. Use a model to describe how *causes* of short and long-term variations in the flow of energy into and out of Earth's systems *result in* changes to climate.

> ***Clarification Statement:*** Emphasis is on the relationships between components that affect the input, output, storage, and redistribution of energy on Earth. Emphasis is on specific cause-and-effect relationships between the factors that affect energy flow (into and out of Earth's systems) and their effects on climate over different timescales.
> ***State Assessment Boundary:*** Assessment is limited to one example of a climate change and its associated impacts. Assessment of the results of changes in climate is limited to direct changes in climate such as surface temperatures and precipitation patterns.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*

Developing and Using Models Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Use a model based on evidence to illustrate and/or predict the relationships between systems or between components.	**ESS1.B: Earth and 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. (*secondary*) **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. Climate changes, which are defined as significant and persistent changes in an area's average or extreme weather conditions can occur if any of Earth's systems change. Scientists can infer these changes from geological evidence. Some climate changes in Earth's history were rapid shifts (caused by natural events, such as volcanic eruptions and meteoric impacts, which suddenly put a large amount of particulate matter into the atmosphere or by abrupt changes in ocean currents, or variations in solar output). Other climate changes were gradual and longer term--due, for example, to solar output variations, or atmospheric changes due to the rise of plants and other life forms that modified the atmosphere via photosynthesis. The timescale of these changes varies from a few to millions of years. Cumulative increases in the atmospheric concentrations of carbon dioxide and other greenhouse gases, whether arising from natural sources or human industrial activity, increase the capacity of Earth to retain energy. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.	**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.

Observable features of student performance by the end of the course:

1. **Components of the model**
    a. Students develop/use a model (conceptual, graphical, physical, etc.) and identify the relevant components, including at least one factor that affects the input of energy, at least one factor that affects the output of energy, and at least one factor that affects the storage and distribution of energy. Factors could include:
        i. changes in Earth's orbit and the orientation of its axis,
        ii. changes in the Sun's energy output,
        iii. configuration of continents resulting from tectonic activity,
        iv. ocean circulation,
        v. atmospheric conditions (including water vapor and CO_2),
        vi. atmospheric circulation,
        vii. volcanic activity,
        viii. glaciation,
        ix. changes in extent or type of vegetation cover, and
        x. human activities.
    b. Students describe the relevant different time scales on which the factors operate.
2. **Relationships**
    a. Students develop/use a model to describe the relationships between components, including:
        i. those that affect input of energy,
        ii. those that affect output of energy, and
        iii. those that affect the storage and redistribution of energy.
3. **Connections**
    a. Students develop/use a model to describe the relationship between energy flow in Earth's systems and changes in climate, including:
        i. specific cause and effect relationships between the factors and the effect on energy flow into and out of Earth's systems and
        ii. the net effect of all the competing factors in changing the climate.

E-ESS2-4 Academic Language

Question/Sentence Stems

- _______ happens to matter as it moves within the system.
- In this system, energy is entering by _______, doing _______ in the system, and leaving the system by _______.
- When you put energy into this system _______.
- The flow of energy causes _______ to occur in the system.
- The energy is entering the system by _______.
- In the system, the cycling of matter _______.
- The matter in the system enters from _______.
- The flow of energy causes _______ to occur in the system as seen with _______ as evidence from the investigation.
- The flow of energy between _______ and _______ drives the changes to the system as seen by _______ because _______.
- _______ shows that _______ is the evidence that energy is being conserved in this system because _______.
- The uneven heating of Earth by the Sun results in _______.
- When a surface _______ (reflects/absorbs) energy, its temperature will _______ (increase/decrease).

Terminology to Support Student Discourse about Phenomena

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- absorption
- acidification
- albedo
- atmosphere
- atmospheric circulation
- atmospheric composition
- axis
- biosphere
- carbon cycle
- carbon dioxide
- climatic pattern
- combustion
- cyclical changes
- electromagnetic radiation
- energy flow
- energy input
- energy output
- energy storage
- entropy
- extreme weather
- fossil fuel
- geosphere
- glacier
- greenhouse gas
- human activity
- hydrosphere
- interdependence
- land system
- meteoric impact
- nitrogen cycle
- ocean current
- ocean system
- oceanic circulation
- orbit
- oxygen
- particulate matter
- photosynthesis
- precipitation
- reflection
- re-radiation
- reservoir/sink
- respiration
- rotation
- sea level
- solar flare
- solar output
- solar radiation
- tectonic activity
- vegetation cover
- volcanic eruption

E-ESS2-5. Investigate the ways that water (given its unique physical and chemical properties) *impacts* various Earth systems.

> ***Clarification Statement:*** Emphasis should be on water's ability to absorb/store and release energy, transmit sunlight, expand when freezing, and dissolve/transport materials. Examples of system interactions could include the hydrogeologic system (weathering, erosion, deposition, soil formation, groundwater formation, and the rock cycle), energy transfer system (weather and climate), and ecosystems (coral reefs and hydrothermal vents).

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Planning and Carrying out Investigations Planning and carrying out investigations in 9- 12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence.	**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 as it changes state; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of the material when mixed with fluid rocks within the mantle. Each of these properties plays a role in how water affects other Earth systems (e.g., ice expansion contributes to rock erosion, or ocean thermal capacity contributes to moderating temperature variations).	**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.

Observable features of student performance by the end of the course:

1. **Identifying the phenomenon under investigation**
    a. Students identify the phenomenon under investigation involving the properties of water and its effect on Earth materials and surface processes.

2. **Identifying the evidence to address the purpose of the investigation**
    a. Students describe the data that will be collected and the evidence to be derived, including:
        i. The properties of water, including:
            1. heat capacity,
            2. density in solid, and liquid states, and
            3. polar nature due to its molecular structure.
        ii. The effect of water properties on energy transfer that causes the patterns of temperature, movement of air, and movement and availability of water at Earth's surface.
        iii. The mechanical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes, for example:
            1. stream transportation and deposition using a stream table, which can be used to infer the ability of water to transport and deposit materials,
            2. erosion using variations in soil moisture content, which can be used to infer the ability of water to prevent or facilitate movement materials, and/or
            3. expansion of water as it freezes, which can be used to infer the ability of water to break rocks into smaller pieces.
        iv. The chemical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes, for example:
            1. solubility of different materials in water, which can be used to infer chemical weathering and recrystallization,
            2. reaction of iron to rust in water, which can be used to infer the role of water in chemical weathering,
            3. data illustrating that water lowers the melting temperature of most solids, which can be used to infer melt generation, and/or
            4. data illustrating that water decreases the viscosity of melted rock, affecting the movement of magma and volcanic eruptions.
3. **Planning the investigation**
    a. Students determine and describe the experimental design, including:
        i. identifying variables and controls,
        ii. the experimental procedure,
        iii. the number of trials,
        iv. the necessary equipment, materials, and techniques, and/or
        v. how the data will be collected.

4. **Refining the experimental design**
    a. Students evaluate the investigation, including:
        i. assessing the accuracy and precision of the data collected,
        ii. limitations of the investigation, and/or
        iii. strength of the data
    b. Students refine the investigation to provide more accurate, precise, and useful data.

E-ESS2-5 Academic Language

Question/Sentence Stems

- By looking at patterns in the data, I/we determined that _______ caused ______.
- _______ caused the patterns I am observing. I know this because _______.
- If _______ happens, I/we predict that ______ will occur.
- Even though I/we cannot see _______, it explains why _______ is happening.
- When I/we change _____ in the system, _______ is affected.
- The evidence _______ presented in the scenario supports the claim that _______ causes _______.
- In order to conclude that _____ caused ____, the following evidence is needed ____.
- Water causes changes to Earth's surface by ______.
- The property of water ______ will result in _______ changes to Earth's surface.

Terminology to Support Student Discourse about Phenomena

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- absorption
- adhesion
- atmosphere
- biosphere
- chemical property
- chemical weathering
- climate
- cohesion
- coral reef
- density
- deposition
- dissolve
- ecosystem
- energy release
- energy transfer
- erosion
- fluid rocks
- freezing point
- frost wedging
- geosphere
- groundwater formation
- heat capacity
- hydrogen (H) bonding
- hydrogeologic system
- hydrologic cycle
- hydrosphere
- hydrothermal vent
- ice expansion
- iron
- lava
- magma
- material transport
- mechanical erosion
- melting point
- molecular structure
- phase change
- physical property
- polarity
- pressure
- recrystallization
- rock cycle
- rust
- sediment
- soil formation
- soil moisture content
- solar energy
- solubility
- stream deposition
- stream table
- stream transportation
- surface tension
- thermal
- viscosity
- volcanic eruption
- water property
- weather

E-ESS2-6. Develop a quantitative model to describe *the cycling of* carbon through the hydrosphere, atmosphere, geosphere, and biosphere.

Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (photosynthesis, chemosynthesis, cellular respiration), providing the foundation for living organisms.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Developing and Using Models Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Develop a model based on evidence to illustrate and/or predict the relationships between systems or between components.	**ESS2.D: Weather and Climate** 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.	**Energy and Matter** The total amount of energy and matter in closed systems is conserved.

Observable features of student performance by the end of the course:

1. **Components of the model**
    a. Students develop/use a model (conceptual, graphical, physical, etc.) and identify the relevant components, including:
        i. relevant concentrations of carbon in the hydrosphere, atmosphere, geosphere, and biosphere and
        ii. represent carbon cycling from one sphere to another.
2. **Relationships**
    a. Students develop/use a model to describe the relationships between components, including:
        i. biogeochemical cycles that occur as carbon flows from one sphere to another,
        ii. relative amount of and rate at which carbon is transferred between spheres,
        iii. capture of carbon by plants, and
        iv. increase in carbon dioxide concentration in the atmosphere due to human activity and the effect on climate.

3. **Connections**
    a. Students develop/use a model to explicitly identify the conservation of matter as carbon cycles through various components of Earth's systems.
    b. Students identify limitations of the model in accounting for Earth's carbon.

E-ESS2-6 Academic Language

Question/Sentence Stems

- One piece of evidence we have for the cycling of matter in this system is _______.
- The flow/transfer of energy causes _______ to occur in the system.
- Energy transfer mechanisms include _______.
- When energy leaves the system, the energy _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- abiotic
- accumulate
- anthropogenic impact
- atmosphere
- bacteria
- basin
- biogeochemical cycle
- biomass
- biosphere
- biotic
- byproduct
- carbon
- carbon cycle
- carbon dioxide (CO_2)
- carbon sink
- cellular respiration
- chemosynthesis
- climate change
- compounds
- concentration
- decay
- decompose
- decomposition
- diffusion
- element
- emissions
- equilibrium
- flux
- fungi
- geosphere
- human activity
- hydrocarbon
- hydrosphere
- inorganic
- input
- marine snow
- organic
- organism
- output
- oxygen
- pathway
- photosynthesis
- phytoplankton
- plankton
- pool
- rate of transfer/flow
- reservoir
- sediment
- sequestered
- soil

E-ESS2-7. Communicate scientific information that illustrates how Earth's systems and life on Earth *change and influence each other over time*.

> ***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 could 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 altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.
> ***State Assessment Boundary:*** Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9-12 builds on K-8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. Communicate scientific and/or technical information or ideas (e.g. about phenomena) in multiple formats (i.e., orally, graphically, textually, mathematically). Use words, tables, diagrams, and graphs, as well as mathematical expressions to communicate their understanding or to ask questions about a system under study.	**ESS2.D: Weather and Climate** Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. The time scales of these changes varied from a few to millions of years. **ESS2.E: Biogeology** As Earth changes, life on Earth adapts and evolves to those changes, so just as life influences other Earth systems, other Earth systems influence life. Life and the planet's nonliving systems can be said to co-evolve. 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.	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.

Observable features of student performance by the end of the course:

1. **Communication**
    a. Students use and cite at least two different formats (for example: oral, graphical, textual, mathematical, etc.) to communicate scientific information about the coevolution of Earth's systems and life on Earth.
2. **Connections**
    a. Students identify and communicate evidence for the coevolution of Earth's systems and life on Earth, including:
        i. scientific explanations about the composition of Earth's atmosphere shortly after its formation,
        ii. current atmospheric conditions,
        iii. evidence for the emergence of photosynthetic organisms,
        iv. evidence for the effect of the presence of free oxygen on evolution and processes in other Earth systems, and
        v. other evidence that changes in the biosphere affect other Earth systems.
    b. Students identify and communicate that the evolution of photosynthetic organisms led to a drastic change in Earth's atmosphere and oceans in which the free oxygen produced caused worldwide deposition of iron oxide formations, increased weather due to an oxidizing atmosphere, and the evolution of life that depends on oxygen for respiration.

E-ESS2-7 Academic Language

Question/Sentence Stems

- The things that stay the same are _______.
- The things that change are _______.
- The things that are changing slowly/quickly in this system are _______.
- The _______(event) changed this system by _______.
- _______ was affected by the change of _______.
- _______ are causing this system to be unstable.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- abiotic
- atmosphere
- atmospheric change
- atmospheric composition
- atmospheric conditions
- biosphere
- biotic
- carbon cycle
- carbon dioxide
- change
- coastline
- coevolution
- continental boundary
- continental shelf
- convection
- coral reef
- crustal deformation
- deposition
- dynamic
- erosion
- evolution
- feedback
- fossils
- fracture zone
- geologic evidence
- geologic time scale
- geoscience
- geosphere
- greenhouse gas
- groundwater
- habitat
- hydrosphere
- igneous rock
- mass extinction
- mass wasting
- metamorphic rock
- microbial
- molten rock
- ocean basin
- ocean trench
- organism
- oxidizing atmosphere
- oxygen
- oxygen-rich
- photosynthesis
- photosynthetic organisms
- plate movement
- plate tectonics
- radioactive
- respiration
- rock formation
- rock strata
- sedimentary rock
- sedimentation
- simultaneous
- soil
- stability
- surface runoff
- time scale
- water cycle
- weather

ESS3 – Earth and Human Activity

E-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources and occurrence of natural hazards *have influenced human activity*.

> ***Clarification Statement:*** Examples of key natural resources could 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).

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories. Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.	**ESS3.A: Natural Resources** Resource availability has guided the development of human society. **ESS3.B: Natural Hazards** Natural hazards and other geologic events have shaped the course of human history by destroying buildings and cities, eroding land, changing the course of rivers, and reducing the amount of arable land. These have significantly altered the sizes of human populations and have driven human migrations. Natural hazards can be local, regional, or global in origin, and their risks increase as populations grow. **ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems. (*secondary*)	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlations and make claims about specific causes and effects.

Observable features of student performance by the end of the course:

1. **Articulating the explanations of phenomena**
    a. Students articulate a statement describing/explaining the relationship between human activity and environmental factors including:
        i. relationships between environmental factors (natural hazards, natural resource availability) and features of human societies (for example: population size, migration patterns, etc.), and
        ii. that technology in modern civilization has mitigated some of the effects of environmental factors on human activity.
2. **Evidence**
    a. Students identify and describe the evidence to construct the explanation, including:
        i. natural hazard occurrences that can affect human activity and have significantly altered the sizes and distributions of human populations in particular regions,
        ii. features of human societies that have been affected by the availability of natural resources, and
        iii. evidence of the dependence of human populations on technological systems to acquire natural resources and to modify physical settings.
3. **Reasoning**
    a. Students use the following chain of reasoning to connect the evidence and support, refute, or revise an explanation, including:
        i. effects of natural hazards and natural resource availability on features of human societies, and
        ii. how technology has changed the cause-and-effect relationship between the development of human society and environmental factors.

E-ESS3-1 Academic Language

Question/Sentence Stems

- By looking at patterns in the data, I/we determined that _______ caused ______.
- _______ caused the patterns I am observing. I know this because _______.
- If _______ happens, I/we predict that_____ will occur.
- The evidence _______ presented in the scenario supports the claim that _______ causes _______.
- In order to conclude that _____ caused _____, the following evidence is needed ____.
- ______ is an example of a natural resource that humans depend on, because ______.
- The distribution of human communities is dependent on the _____________ of natural resources.
- Scarcity of natural resources will result in _______.
- Climate change will negatively affect human activity because _______.
- Natural hazards will negatively affect human activity because _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- arable land
- atmosphere
- availability
- biosphere
- climate change
- destruction
- drought
- earthquake
- economic cost
- erosion
- fertile soil
- flood
- fossil fuels
- frequency
- freshwater
- groundwater
- heatwave
- human activity
- hurricane
- hydrosphere
- interior process
- landslide
- magnitude
- mass wasting
- migration
- mineral concentration
- mitigation
- modern civilization
- natural hazard
- natural resource
- non-renewable
- optimal
- population growth
- population size
- renewable
- resource availability
- risk
- river course
- river delta
- scarcity
- severe weather
- soil erosion
- surface process
- technology
- tsunami
- volcanic eruption
- wildfire

E-ESS3-2. Evaluate competing design solutions that address *the impacts of* developing, managing, and using Earth's energy and mineral resources.

> ***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, forestry, and risk/benefit analysis of the production of conventional, unconventional, or renewable energy resources.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student- generated sources of evidence consistent with scientific knowledge, principles, and theories. Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student generated sources of evidence, prioritized criteria, and trade off considerations.	**ESS3.A: Natural Resources** 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. **ETS1.A: Defining and Delimiting an Engineering Problem** Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. **ETS1.B: Developing Possible Solutions** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. Testing should lead to improvements in the design through an iterative procedure. (*secondary*) **ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World** Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. Analysis of costs and benefits is a critical aspect of decisions about technology. (*secondary*)	**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.

Observable features of student performance by the end of the course:

1. **Identifying the design solution**
    a. Students identify and describe the problem each design solution addresses.
    b. Students identify the solution that has the most preferred cost-benefit ratios.
2. **Identifying evidence**
    a. Students identify and describe the evidence for the design solutions, including:
        i. societal needs for that energy and/or mineral resource,
        ii. extraction and/or development cost,
        iii. costs and benefits of the design solution, and
        iv. feasibility, costs, and benefits of recycling and/or reusing the mineral resource, if applicable.
3. **Evaluating and critiquing the design solution**
    a. Students evaluate the design solutions, including:
        i. relative strengths and weaknesses of the design solution, based on economic, environmental, and geopolitical costs, risks, and benefits,
        ii. reliability and validity of the evidence used to evaluate, and
        iii. constraints, including:
            1. cost,
            2. safety,
            3. reliability,
            4. aesthetics,
            5. cultural effects, and
            6. environmental effects.
4. **Reasoning and synthesis**
    a. Students use logical arguments based on the evaluation of the design solutions, costs and benefits, empirical evidence, and scientific understanding to support one design over the other(s).
    b. Students acknowledge that a decision on the “best” solution may change over time as engineers and scientists work to increase the benefits of design solutions while decreasing cost and risk.

E-ESS3-2 Academic Language

Question/Sentence Stems

- By looking at patterns in the data, I/we determined that _______ caused ______.
- _______ caused the patterns I am observing. I know this because _______.
- If _______ happens, I/we predict that_____ will occur.
- The evidence _______ presented in the scenario supports the claim that _______ causes _______.
- In order to conclude that _____ caused _____, the following evidence is needed ____.
- ______ is an example of a natural resource that humans depend on, because ______.
- The distribution of human communities is dependent on the _____________ of natural resources.
- Scarcity of natural resources will result in _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- abiotic
- aesthetics
- agriculture
- aquifer
- basin
- biotic
- conservation
- constraints
- consumption
- conventional resource
- cost-benefit analysis
- criteria
- depletion
- development
- domestic use
- dynamic
- economic cost
- economic impact
- economics
- empirical evidence
- environmental impact
- exponential
- extinction
- extraction
- feasibility
- feedback
- fertile land
- forestry
- fossil fuel
- fragmentation
- groundwater
- hydrothermal
- irreversible
- logarithmic
- manufacturing
- metal
- mineral resource
- mining
- mitigation
- modification
- non-renewable
- oil shale
- optimal solution
- per-capita
- pollution
- production
- recycle
- regulation
- reliability
- renewable
- resource management
- reuse
- reversible
- risk/benefit analysis
- safety
- social impact
- societal
- solar radiation
- species
- stabilize
- sustainability
- tar sand
- technology
- timber
- unconventional resource
- urban planning
- waste management
- wetland

E-ESS3-3. Use computational representation to illustrate the relationships among the management of Earth's resources, the *sustainability of human populations*, and biodiversity.

> ***Clarification Statement:*** Examples of factors that affect the management of natural resources could include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability could include agricultural efficiency, levels of conservation, urban planning, as well as local and international policies.
> ***State Assessment Boundary:*** Assessment for computational thinking is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.	**ESS3.C: Human Impacts on Earth Systems** The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. When the source of an environmental problem is understood and international agreement can be reached, human activities can be regulated to mitigate global impacts (e.g., acid rain and the ozone hole near Antarctica). **ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems. (*secondary*) New technologies can have deep impacts on society and the environment, including some that were not anticipated. (*secondary*)	**Stability and Change** Feedback (negative or positive) can stabilize or destabilize a system.

Observable features of student performance by the end of the course:

1. **Representation**
    a. Students develop/use a computational model (for example: spreadsheet, multi-parameter program) that includes representations of the relevant components of an identified ecosystem, including:
        i. natural resource,
        ii. sustainability of the human population,
        iii. biodiversity, and
        iv. the effect of technology.
2. **Mathematical and/or computational modeling**
    a. Students develop/use a computational model to describe simplified realistic (corresponding to real-world data) relationships between variables to indicate and understanding of the factors (for example: cost, technology, etc.) that affect the management of natural resources, human sustainability, and biodiversity, for example:
        i. A relationship could be described that the amount of a natural resource does not affect the sustainability of human populations in a given ecosystem without appropriate technology that makes use of the resource; or a relationship could be described that if a given ecosystem is not able to sustain biodiversity, its ability to sustain a human population is also small.
    b. Students develop/use a computational model (for example: spreadsheet, multi-parameter program) that models each component and its simplified mathematical relationship to other components, for example:
        i. S=C*B*R*T where:
            1. S is sustainability of human populations,
            2. C is a constant,
            3. B is biodiversity,
            4. R is the natural resource, and
            5. T is a technology used to extract the resource, so that:
                a. if there is zero natural resource (R=0), zero technology to extract that resource (T=0), or zero biodiversity (B=0), the sustainability of human populations is also zero, and
        ii. B=B1+C*T where:
            1. B is biodiversity,
            2. B1 is a constant baseline biodiversity,
            3. C is a constant that expresses the effect of technology, and
            4. T is a technology, so that:
                a. a technology could either increase or decrease biodiversity depending on the value of C.

   c. Students develop/use a computational model that contains user-controlled variable that can illustrate relationships among the components.

3. **Analysis**
   a. Students develop/use a computational model and use the results to:
      i. Illustrate the effect of one component by altering other components in the system or the relationship between components.
      ii. Identify the effects of technology on the interactions between human populations, natural resources, and biodiversity.
      iii. Identify feedbacks between the components and whether the feedback stabilizes or destabilizes the system.
   b. Students compare the results to real-world example(s) and determine if the model can be viewed as realistic.
   c. Students identify and describe limitations of the model.

E-ESS3-3 Academic Language

Question/Sentence Stems

- The data shows that _______ changes over time.
- _______ supports the idea that _______ has changed over geologic time.
- The components that are changing slowly/quickly in this system are _______.
- The _______(event) changed this system by _______.
- _______ was affected by the change of _______.
- _______ are causing/caused this system to be unstable.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- abiotic
- acid rain
- agriculture
- anthropogenic impact
- aquifer
- baseline
- basin
- biodiversity (B=B1+CT)
- biome
- biosphere
- biotic
- conservation
- constant
- consumption
- cost
- depletion
- destabilize
- dynamic
- ecological
- economic cost
- ecosystem
- efficiency
- energy production
- environmental cost
- environmental problem
- exponential
- extinction
- extract
- feedback
- fertile land
- fragmentation
- geopolitical cost
- geosphere
- global impact
- human activity
- human population
- hydrologic cycle
- hydrosphere
- hydrothermal
- irreversible
- logarithmic
- manufacturing
- mineral
- mining
- mitigation
- modern civilization
- natural resource
- non-renewable
- oil shale
- ozone hole
- per-capita
- recycle
- regulation
- renewable
- resource extraction
- resource management
- reuse
- reversible
- societal
- societal cost
- solar radiation
- stabilize
- sustainability (S=CBRT)
- tar sand
- technology
- timber
- urban planning
- waste management
- watershed
- wetland

E-ESS3-4. Evaluate or refine a technological solution *that reduces impacts* of human activities on natural systems.

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).

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories. 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.	**ESS3.C: Human Impacts on Earth Systems** Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. **ETS1.B: Developing Possible Solutions** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. Testing should lead to improvements in the design through an iterative procedure. **EST2.B: Influence of Engineering, Technology, and Science on Society and the Natural World** Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.	**Stability and Change** Feedback (negative or positive) can stabilize or destabilize a system.

Observable features of student performance by the end of the course:

1. **Identifying the design solution and supporting evidence**
    a. Students use scientific information to generate a number of possible refinements to a technological solution. Students:
        i. describe the system being impacted and how human activity is affecting that system,
        ii. identify the scientific knowledge and reasoning on which the solution is based,
        iii. describe how the solution functions and may be stabilizing or destabilizing the natural system, and
        iv. refine the solution that reduces human impact on natural systems.
2. **Identifying additional relevant evidence**
    a. Students evaluate the solution for:
        i. cost,
        ii. aesthetics,
        iii. its impact on overall environmental stability and changes,
        iv. reliability,
        v. safety, and/or
        vi. social, cultural, and environmental impacts.
3. **Evaluating and critiquing the design solution**
    a. Students describe how the refinement will improve the solution to increase benefits and/or decrease costs or risks to people and the environment.
    b. Students evaluate the proposed refinements for:
        i. effects on the overall stability of and changes in natural systems,
        ii. cost,
        iii. safety,
        iv. aesthetics,
        v. reliability, and
        vi. social, cultural, and environmental impacts.

E-ESS3-4 Academic Language

Question/Sentence Stems

- The things that stay the same are _______.
- The things that change are _______.
- The things that are changing slowly/quickly in this system are _______.
- The _______(event) changed this system by _______.
- _______ was affected by the change of _______.
- _______ are causing this system to be unstable.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- abiotic
- aesthetics
- agriculture
- aquifer
- areal changes
- atmosphere
- availability
- basin
- biodiversity
- biomass
- biosphere
- biotic
- conservation
- constraints
- consumption
- criteria
- depletion
- destabilize
- development
- domestic use
- dynamic
- economic cost
- economic impact
- economics
- ecosystem degradation
- environmental impact
- exponential
- extinction
- extract
- feedback
- fertile land
- fragmentation
- geoengineering
- geosphere
- global temperature
- human activity
- hydrologic cycle
- hydrosphere
- hydrothermal
- impact reduction
- irreversible
- land surface use
- large-scale
- livestock
- logarithmic
- manufacturing
- metal
- mining
- mitigation
- non-renewable
- oil shale
- optimal solution
- per-capita
- pollutant
- production
- recycle
- reduce
- refine
- regulation
- reliability
- renewable
- reuse
- reversible
- scarcity
- societal
- societal impact
- solar radiation
- species diversity
- stabilize
- tar sand
- technology
- timber
- urban development
- urban planning
- waste management
- watershed
- wetland

E-ESS3-5. Analyze data and the results from global climate models **to make an evidence-based forecast** *of the current rate of* regional or global climate change and associated future impacts to Earth's systems.

> ***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).
> ***State Assessment Boundary:*** Assessment is limited to one example of a climate change and its associated impacts.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Analyzing and Interpreting Data Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. Analyze data using computational models in order to make valid and reliable scientific claims.	**ESS3.D: Global Climate Change** Global climate models are often used to understand the process of climate change because these changes are complex and can occur slowly over Earth's history. Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.	**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.

Observable features of student performance by the end of the course:

1. **Organizing data**
    a. Students organize data from global climate models and climate observations over time that relate to the effect of climate change on the physical parameters and/or chemical composition of Earth systems, including the:
        i. atmosphere,
        ii. geosphere,
        iii. hydrosphere, and/or
        iv. cryosphere.

2. **Identifying relationships**
    a. Students analyze data to determine the relationships within the datasets, including:
        i. changes over time on multiple scales and
        ii. relationships between quantities.
3. **Interpreting data**
    a. Students use the analyzed data to explain an aspect of past or present climate and the associated physical parameter (for example: temperature, precipitation, sea level, etc.) and/or chemical composition (for example: ocean pH, etc.) of a system.
    b. Students use the analyzed data to predict the future effect of an aspect of climate change on physical parameters and/or chemical composition of a system.
        i. Students describe whether the predicted effect on the system is reversible or irreversible.
        ii. Students identify and describe one source of uncertainty in the prediction.
    c. Students include the following in the interpretation of the data:
        i. make a statement regarding how variation or uncertainty in the data (for example: limitations, accuracy, bias, scale, instrumentation, etc.) may affect the interpretation and
        ii. identify the limitations of the models that provided the simulation data and ranges for their predictions.

E-ESS3-5 Academic Language

Question/Sentence Stems

- The things that stay the same are _______.
- The things that change are _______.
- The things that are changing slowly/quickly in this system are _______.
- The _______(event) changed this system by _______.
- _______ was affected by the change of _______.
- _______ are causing this system to be unstable.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- accuracy
- acid rain
- anthropogenic
- atmosphere
- atmospheric change
- atmospheric composition
- average air temperature
- average sea surface temperature
- biosphere
- carbon cycle
- carbon footprint
- climate change
- concentration
- cryosphere
- electromagnetic radiation
- extinction
- forecast
- geochemical reaction
- geoscience
- geosphere
- glacial ice volume
- glacier
- global climate records
- global temperature
- global warming
- greenhouse effect
- greenhouse gas
- human impact
- hydrosphere
- ice core
- input
- instrumentation
- irreversible
- limitation
- methane
- Milankovitch cycle
- ocean consumption
- orientation
- output
- pH
- precipitation
- probabilistic
- radiation
- redistribute
- reversible
- sea level
- temperature
- trends
- volcanic ash

E-ESS3-6. Use a computational representation to illustrate *the relationships among* Earth systems and how those relationships are being modified due to human activity.

> ***Clarification Statement:*** Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. One example of this relationship is how human activities can create changes in the atmosphere including an increase in carbon dioxide that has many far-reaching effects, including changes in photosynthetic biomass on land, ocean acidification, and storm intensity.
> ***State Assessment Boundary:*** Assessment does not include running computational representations and is limited to using the published results of scientific computational models.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.	**ESS2.D: Weather and 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. Hence the outcomes depend on human behaviors as well as on natural factors that involve complex feedback among Earth's systems. (*secondary*) **ESS3.D: Global Climate Change** 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. **ESS3.B: Natural Hazards** Human activities can contribute to the frequency and intensity of some natural hazards.	**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.

Observable features of student performance by the end of the course:

1. **Representation**
   a. Students develop/use a computational model of interacting Earth systems and describe the relevant components, including:
      i. relevant system components,
      ii. system boundaries,
      iii. initial conditions,
      iv. inputs and outputs, and
      v. relationships that determine the interaction (for example: relationship between atmospheric CO_2 and production of photosynthetic biomass and ocean acidification).
2. **Mathematical and/or computational modeling**
   a. Students develop/use a computational model of Earth systems and describe relationships among at least two of Earth's systems, including how the relevant components in each individual Earth system can drive changes in another, interacting Earth system.
3. **Analysis**
   a. Students develop/use a computational model as evidence to describe how human activity could affect the relationships between Earth's systems.

E-ESS3-6 Academic Language

Question/Sentence Stems

- The key components of the system are _______.
- In the system, _______ and _______ are shown in the model.
- In the system, _______ and _______ work together to _______.
- In the system, _______ and _______ interact in _______ way.
- If you change _______ in the system, _______ will occur.
- In the system, ______ is not shown in the model. This is not shown because _______.
- The key assumptions to the model of my system are _______ this affects the reliability of the model because _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- abiotic
- absorption
- agriculture
- anthropogenic
- atmosphere
- atmospheric change
- atmospheric composition
- average air temperature
- average sea surface temperature
- biodiversity
- biomass
- biosphere
- biotic
- carbon cycle
- carbon dioxide
- carbon footprint
- climate change
- combustion
- concentration
- conservation
- consumption
- economic impact
- electromagnetic radiation
- environmental impact
- extinction
- extract
- feedback
- fertile land
- final
- fossil fuel
- geochemical reaction
- geopolitical impact
- geoscience
- geosphere
- glacier
- global climate records
- global temperature
- greenhouse gas
- human activity
- hydrosphere
- ice core
- initial
- input
- manufacturing
- metal
- methane
- Milankovitch cycle
- mining
- modification
- natural hazard
- non-renewable
- ocean acidification
- oil shale
- orientation
- output
- per-capita
- photosynthetic biomass
- probabilistic
- radiation
- redistribute
- renewable
- sea level
- societal impact
- tar sand
- technology
- timber
- trends
- volcanic ash
- wetland

E-ESS3-7. Create an argument, based on evidence that describes how changes in climate on Earth *have affected* human activity.

Clarification Statement: Emphasis is on changes in climate that influence past, modern, or future human activities. Examples of key changes in climate that can affect populations or drive mass migrations could include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

Science and Engineering Practices	Disciplinary Core Ideas	*Crosscutting Concepts*
Engaging in Argument from Evidence Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world(s). 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. Construct a scientific argument based on data and evidence.	**ESS3.D: Global Climate Change** Impacts of climate change--for example, increased frequency of severe storms due to ocean warming-- have begun to influence human activities. 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. Thus, science and engineering will be essential both to understanding the possible impacts of global climate change and to informing decisions about how to slow its rate and consequences for humanity as well as for the rest of the planet. The impacts of climate change are uneven and may affect some regions, species, of human populations more severely than others. By using science-based predictive models, humans can anticipate long-term change more effectively than ever and plan accordingly **ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems. (*secondary*)	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Observable features of student performance by the end of the course:

1. **Developing a claim**
    a. Students make a claim that changes in climate on Earth have affected human activity, including:
        i. relationships between climate change and features of human societies (for example: population size, migration patterns, etc.), and
        ii. that technology in modern civilization has mitigated some of the effects of environmental factors on human activity.
2. **Identifying scientific evidence**
    a. Students identify and describe the evidence that supports the claim, including:
        i. changes in climate (for example: increased incidence and severity of storms, etc.) that can affect human activity (for example: agriculture, etc.) and human populations, and that can drive mass migrations,
        ii. evidence of the dependence of human populations on technological systems to acquire natural resources and to modify physical settings.
3. **Evaluating and critiquing evidence**
    a. Students identify strengths and weaknesses of the evidence used to support the claim, including:
        i. types of sources,
        ii. sufficiency, including validity and reliability, of the evidence to make and defend the claim, and/or
        iii. any alternative interpretations of the evidence and why the evidence supports or does not support the student's claim, as opposed to any other claims.
4. **Reasoning and synthesis**
    a. Students use the following chain of reasoning to connect the evidence:
        i. effects of climate change on features of human societies, and
        ii. how technology has changed the cause-and-effect relationship between the development of human society and environmental factors.
    b. Students defend a claim against counterclaims by evaluating counterclaims and by describing the connections between the relevant and appropriate evidence to the strongest claim.

E-ESS3-7 Academic Language

Question/Sentence Stems

- By looking at patterns in the data, I/we determined that _______ caused ______.
- _______ caused the patterns I am observing. I know this because _______.
- If _______ happens, I/we predict that_____ will occur.
- The evidence _______ presented in the scenario supports the claim that _______ causes _______.
- In order to conclude that _____ caused ____, the following evidence is needed ____.
- Climate change will negatively affect human activity because _______.

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- geopolitical impact
- geoscience
- geosphere
- glacier
- global climate records
- global temperature
- greenhouse gas
- human activity
- hydrosphere
- ice core
- manufacturing
- mass migration
- metal
- methane
- Milankovitch cycle
- mining
- mitigate
- modern civilization
- natural resource
- non-renewable
- ocean warming
- oil shale
- orientation
- per-capita
- precipitation
- probabilistic
- radiation
- redistribute
- regional pattern
- renewable
- sea level
- societal impact
- tar sand
- technology
- timber
- trends
- volcanic ash
- wetland

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