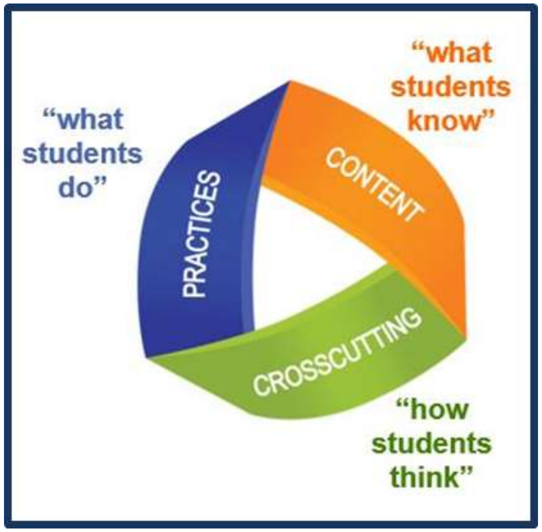
Ledyard Public Schools
Ledyard High School
NGSS Science Curriculum
Systems and Sustainability



½ credit course
Required for graduation

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Quick Links

A Framework for K-12 Science Education	NGSS Website	K-12 Endpoint Progression

District Philosophy

Ledyard's vision for K-12 inquiry based science is to engage students in scientific and engineering practices as they apply crosscutting concepts to deepen their understanding of the core ideas in these fields.

A New Vision for Science Education

Implications of the Vision of the Framework for K-12 Science Education and the Next Generation Science Standards

SCIENCE EDUCATION WILL INVOLVE LESS:	SCIENCE EDUCATION WILL INVOLVE MORE:
Rote memorization of facts and terminology.	Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning.
Learning of ideas disconnected from questions about phenomena.	Systems thinking and modeling to explain phenomena and to give a context for the ideas to be learned.
Teachers providing information to the whole class.	Students conducting investigations, solving problems, and engaging in discussions with teachers' guidance.
Teachers posing questions with only one right answer.	Students discussing open-ended questions that focus on the strength of the evidence used to generate claims.
Students reading textbooks and answering questions at the end of the chapter.	Students reading multiple sources, including science-related magazine and journal articles and web-based resources; students developing summaries of information.
Pre-planned outcome for "cookbook" laboratories or hands-on activities.	Multiple investigations driven by students' questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas.
Worksheets.	Student writing of journals, reports, posters, and media presentations that explain and argue.
Oversimplification of activities for students who are perceived to be less able to do science and engineering	Provision of supports so that all students can engage in sophisticated science and engineering practices

Source: National Research Council. (2015). *Guide to Implementing the Next Generation Science Standards* (pp. 8-9). Washington, DC: National Academies Press.
http://www.nap.edu/catalog/18802/guide-to-implementing-the-next-generation-science-standards

Three Dimensions of the *Next Generation Science Standards*: Practices of Science and Engineering:

Scientific and Engineering Practices Matrix - SEP (appendix F)

Asking Questions and Defining Problems

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested.

Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify the ideas of others.

Planning and Carrying Out Investigations

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

Analyzing and Interpreting Data

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

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

Developing and Using Models

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

Constructing Explanations and Designing Solutions

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

Engaging in Argument from Evidence

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

Using Mathematics and Computational Thinking

In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions. Statistical methods are frequently used to identify significant patterns and establish correlational relationships.

Obtaining, Evaluating, and Communicating Information

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

NGSS@ NSTA STEM STARTS HERE

www.nsta.org/ngss

Three Dimensions of the *Next Generation Science Standards*: Disciplinary Core Ideas:

Disciplinary Core Ideas Matrix - DCI (appendix E)			
Physical Science	**Life Science**	**Earth and Space Science**	**Engineering, Technology, and the Application of Science**
PS1: Matter and Its Interactions PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions PS1.C: Nuclear Processes **PS2: Motion and Stability: Forces and Interactions** PS2.A: Forces and Motion PS2.B: Types of Interactions PS2.C: Stability and Instability in Physical Systems **PS3: Energy** PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.C: Relationship Between Energy and Forces PS3.D: Energy in Chemical Processes and Everyday Life **PS4: Waves and Their Applications in Technologies for Information Transfer** PS4.A: Wave Properties PS4.B: Electromagnetic Radiation PS4.C: Information Technologies and Instrumentation	**LS1: From Molecules to Organisms: Structures and Processes** LS1.A: Structure and Function LS1.B: Growth and Development of Organisms LS1.C: Organization for Matter and Energy Flow in Organisms LS1.D: Information Processing **LS2: Ecosystems: Interactions, Energy, and Dynamics** LS2.A: Interdependent Relationships in Ecosystems LS2.B: Cycles of Matter and Energy Transfer in Ecosystems LS2.C: Ecosystem Dynamics, Functioning, and Resilience LS2.D: Social Interactions and Group Behavior **LS3: Heredity: Inheritance and Variation of Traits** LS3.A: Inheritance of Traits LS3.B: Variation of Traits **LS4: Biological Evolution: Unity and Diversity** LS4.A: Evidence of Common Ancestry and Diversity LS4.B: Natural Selection LS4.C: Adaptation LS4.D: Biodiversity and Humans	**ESS1: Earth's Place in the Universe** ESS1.A: The Universe and Its Stars ESS1.B: Earth and the Solar System ESS1.C: The History of Planet Earth **ESS2: Earth's Systems** ESS2.A: Earth Materials and Systems ESS2.B: Plate Tectonics and Large-Scale System Interactions ESS2.C: The Roles of Water in Earth's Surface Processes ESS2.D: Weather and Climate ESS2.E: Biogeology **ESS3: Earth and Human Activity** ESS3.A: Natural Resources ESS3.B: Natural Hazards ESS3.C: Human Impacts on Earth Systems ESS3.D: Global Climate Change	**ETS1: Engineering Design** ETS1.A: Defining and Delimiting an Engineering Problem ETS1.B: Developing Possible Solutions ETS1.C: Optimizing the Design Solution **ETS2: Links Among Engineering, Technology, Science, and Society** ETS2.A: Interdependence of Science, Engineering, and Technology ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World

Developed by NSTA based on content from the *Framework for K-12 Science Education* and supporting documents for the *May 2012 Public Draft of the NGSS*

Three Dimensions of the *Next Generation Science Standards*: Crosscutting Concepts:

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

Developed by NSTA based on content from the *Framework for K-12 Science Education* and supporting documents for the *May 2012 Public Draft of the NGSS*

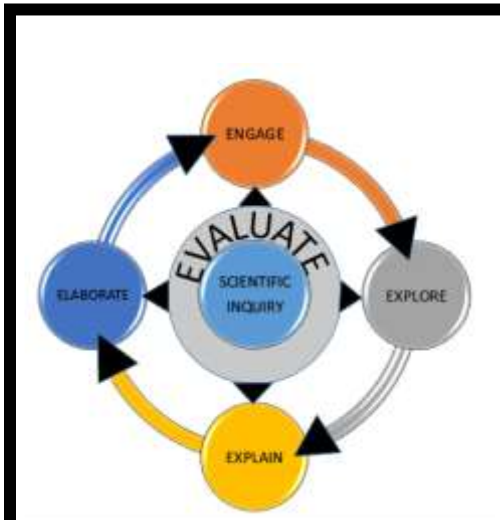
Connections to the Nature of Science

Nature of Science Practices	Nature of Science Crosscutting Concepts
These understandings about the nature of science are closely associated with the science and engineering practices, and are found in that section of the foundation box on a standards page. More information about the Connections to Engineering, Technology and Applications of Science can be found in Appendix H.	These understandings about the nature of science are closely associated with the crosscutting concepts, and are found in that section of the foundation box on a standards page. More information about the Connections to Engineering, Technology and Applications of Science can be found in Appendix H.
Scientific Investigations Use a Variety of Methods	Science is a Way of Knowing
Science Knowledge is Based on Empirical Evidence	Scientific Knowledge Assumes and Order and Consistency in Natural Systems
Scientific Knowledge is Open to Revision in Light of New Evidence	Science is a Human Endeavor
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena.	Science Addresses Questions About the Natural and Material World

How does Ledyard Define Inquiry?

Inquiry is defined as a way of seeking information, knowledge, or truth through questioning. Inquiry is a way for a learner to acquire new information and data and turn it into useful knowledge. Inquiry involves asking good questions and developing robust investigations from them. Inquiry also involves considering possible solutions and consequences. A third component of inquiry is separating evidence based claims from common opinion, and communicating claims with others, and acting upon these claims when appropriate. Questions lead to gathering information through research, study, experimentation, observation, or interviews. During this time, the original question may be revised, a line of research refined, or an entirely new path may be pursued. As more information is gathered, it becomes possible to make connections and allows individuals to construct their own understanding to form new knowledge. Sharing this knowledge with others develops the relevance of the learning for both the student and a greater community. Sharing is followed by reflection and potentially more questions, bringing the inquiry process full circle.

Inquiry 5 Science Teaching Model



Engagement	Object, event or question used to engage students. Connections facilitated between what students know and can do.
Exploration	Objects and phenomena are explored. Hands-on activities, with guidance.
Explanation	Students explain their understanding of concepts and processes. New concepts and skills are introduced as conceptual clarity and cohesion are sought.
Elaboration	Activities allow students to apply concepts in contexts, and build on or extend understanding and skill.
Evaluation	Students assess their knowledge, skills and abilities. Activities permit evaluation of student development and lesson effectiveness.

Course Overview

This course addresses three major themes. The first is **Earth's Place in the Universe**, which describes the universe as a whole and addresses its grand scale in both space and time. The next is **Earth's Systems**, which encompasses the processes that drive Earth's conditions (such as plate tectonics, erosion, and climate) and its continual evolution. Emphasis is placed on the last theme, **Earth and Human Activity**, which addresses society's interactions with the planet focusing on the sustainable use of its resources. This course is a continuation of Earth and Space Sciences and builds on the knowledge and skills from K-8, supporting high school students in meeting NGSS performance expectations.

Core Idea : ESS 1: Earth's Place in the Universe (6 class periods)

What is the universe, and what is Earth's place in it?

The planet Earth is a tiny part of a vast universe that has developed over a huge expanse of time. The history of the universe, and of the structures and objects within it, can be deciphered using observations of their present condition together with knowledge of physics and chemistry. Similarly, the patterns of motion of the objects in the solar system can be described and predicted on the basis of observations and an understanding of gravity. Comprehension of these patterns can be used to explain many Earth phenomena, such as day and night, seasons, tides, and phases of the moon. Observations of other solar system objects and of Earth itself can be used to determine Earth's age and the history of large-scale changes in its surface.

Component Ideas	NGSS Performance Expectations
ESS1-A: THE UNIVERSE AND ITS STARS Compelling question: *What is the universe and what goes on in stars?*	HS-ESS1-1, HS-ESS1-2, HS-ESS1-3
ESS1-B: EARTH AND THE SOLAR SYSTEM Compelling question: *What are the predictable patterns caused by Earth's movement in the solar system?*	HS-ESS1-4
ESS1-C: THE HISTORY OF PLANET EARTH Compelling question: *How do people reconstruct and date events in Earth's planetary history?*	HS-ESS1-5, HS-ESS1-6

NGSS Performance Expectations *Students who demonstrate understanding can:*
HS-ESS1-1 **Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.** Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries. Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.
HS-ESS1-2, PS4.B **Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.** Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).
HS-ESS1-3 **Communicate scientific ideas about the way stars, over their life cycle, produce elements.** **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. **Assessment Boundary:** Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.
HS-ESS1-4 **Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.** **Clarification Statement:** Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.

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.
HS-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).
HS-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 along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.

ESS1-A: THE UNIVERSE AND ITS STARS (HS-ESS1-1, HS-ESS1-2, HS-ESS1-3) Compelling Question: *What is the universe and what goes on in stars?*
Suggested Content –Vocabulary in bold
ESS1-A: THE UNIVERSE AND ITS STARS: *What is the universe and what goes on in stars?* • The **sun** is but one of a vast number of stars in the **Milky Way** galaxy, which is one of a vast number of **galaxies** in the **universe**. • The universe began with the **Big Bang**.   ○ This theory provides an explanation of observations of distant galaxies receding from our own, of the measured **composition of stars** and of the primordial **radiation** that still fills the universe.

- Nearly all observable matter in the universe is **hydrogen** or **helium** which formed in the first minutes after the Big Bang.
  - Heavier elements continue to form within the **cores of stars**.
  - **Nuclear fusion** is the process responsible form the formation of all **atomic nuclei** lighter than and including iron. This process also releases the energy seen as starlight.
  - Heavier elements are produced when certain massive stars achieve a **supernova** stage and explode.
- 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.
  - Stars go through a sequence of developmental stages.
  - Material from earlier stars that exploded as supernovas is recycled to form younger stars.
  - The sun is a medium-sized star about halfway through its predicted **life span** of about 10 billion years.

Disciplinary Core Ideas	Observable features of student performance
• The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1) • Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (HS-ESS1-1,PS3.D) • The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2, HS-ESS1-3) • The Big Bang theory is supported	HS-ESS1-1 1. Components of the model a. Students use evidence to develop a model in which they identify and describe the relevant components, including: i. Hydrogen as the sun's fuel; ii. Helium and energy as the products of fusion processes in the sun; and iii. That the sun, like all stars, has a life span based primarily on its initial mass, and that the sun's lifespan is about 10 billion years. 2. Relationships a. In the model, students describe relationships between the components, including a description* of the process of radiation, and how energy released by the sun reaches Earth's system. 3. Connections a. Students use the model to predict how the relative proportions of hydrogen to helium change as the sun ages.

by observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS-ESS1-2, HS-ESS1-3) • Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (HS-ESS1-2, HS-ESS1-3) • 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) (HS-ESS1-2, HS-ESS1-3, PS4.B)	b. Students use the model to qualitatively describe the scale of the energy released by the fusion process as being much larger than the scale of the energy released by chemical processes. c. Students use the model to explicitly identify that chemical processes are unable to produce the amount of energy flowing out of the sun over long periods of time, thus requiring fusion processes as the mechanism for energy release in the sun. HS-ESS1-2 1. Articulating the explanation of phenomena a. Students construct an explanation that includes a description* of how astronomical evidence from numerous sources is used collectively to support the Big Bang theory, which states that the universe is expanding and that thus it was hotter and denser in the past, and that the entire visible universe emerged from a very tiny region and expanded. 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. b. Students use a variety of valid and reliable sources for the evidence, which may include students' own investigations, theories, simulations, and peer review. c. Students describe the source of the evidence and the technology used to obtain that evidence. 3. Reasoning a. Students use reasoning to connect evidence, along with 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, to construct the explanation for the early universe (the Big Bang theory). Students describe the following chain of reasoning for their explanation: 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 background cosmic 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 that evolved through different stages as it expanded and cooled (e.g., the formation of nuclei from colliding protons and neutrons predicts the hydrogen-helium ratio [numbers not expected from students], later formation of atoms from nuclei plus electrons, background radiation was a relic from that time). 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. HS-ESS1-3 1. Communication Style and Format a. Students use at least two different formats (e.g., oral, graphical, textual, and mathematical) to communicate scientific information, and cite the origin of the information as appropriate. 2. Connecting the DCI's and the CCC's a. Students identify and communicate the relationships between the life cycle of the stars, the production of elements, and the conservation of the number of protons plus neutrons in stars. Students identify that atoms are not conserved in nuclear fusion, but the total number of protons plus neutrons is conserved. b. Students describe that: i. Helium and a small amount of other light nuclei (i.e., up to lithium) were formed from high-energy collisions starting 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 processes of nuclear fusion, which also releases energy. iii. Supernova explosions of massive stars are the mechanism by which elements more massive than iron are produced. 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 and distance to Earth.

Crosscutting Concepts

Energy and Matter

- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-ESS1-3), (HS-PS1-8), (HS-HS-ESS1-1)
- Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems. (HS-ESS1-2)

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1)
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-ESS1-2)
- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-2)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-2)

Science and Engineering Practices

Developing and Using Models

- Modeling in 9–12 builds on K–8 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 worlds.
    - Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8),(HS-ESS1-1)

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 students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS1-2)

Obtaining, Evaluating, and Communicating Information

- Communicate scientific ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-ESS1-3)

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-ESS1-2)

Grade Band Endpoint for ESS1-A
By the end of grade 12: The star called the sun is changing and will burn out over a life span of approximately 10 billion years. The sun is just one of more than 200 billion stars in the Milky Way galaxy, and the Milky Way is just one of hundreds of billions of galaxies in the universe. The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from earth. K-12 Endpoint Progression

Suggested Projects
• The Life Cycle of Stars- This multi-faceted lesson has students exploring what makes a star a star, including an in-depth focus on the process of nuclear fusion in the core of stars. Additionally, students also get a glimpse of the astronomical "life cycle" of stars in our galaxy • The Big Bang- Students identify the two main pieces of evidence to support the Big Bang, as well as holistically exploring the Big Bang as a cosmological theory of the beginning of the universe

• Earth Science Week-classroom activities-Classroom Activities, categorized by the Next Generation Science Standards (NGSS) • NGSS-HUB (project ideas)- link to various activities	
Modifications to Content/Differentiation	
Priority	**Enrichment**
-To include suggestions regarding depth of coverage *-Minimum depth of coverage* - The energy produced in stars is produced via a nuclear reaction (fusion) rather than a chemical reaction and involves a much larger amount of energy per kilogram of material. The nuclear equations will not be assessed.	*-To include suggested extensions to investigations* *-Increased depth* -Nuclear fusion reactions are shown and conservation of mass and energy can be discussed. - The red shift can be explained in more detail using the Doppler effect and semi-quantitatively with the wave equation, $c=\lambda\nu$.
Suggested Assessments	
• Traditional assessment: multiple choice and free response questions, or • The above project(s) using the eight science and engineering practice standards, or • A combination of traditional assessment with project, or • Other format of teacher's choice	

ESS1-B: EARTH AND THE SOLAR SYSTEM (HS-ESS1-4) Compelling Question: ***What are the predictable patterns caused by Earth's movement in the solar system?*** *Unless otherwise specified, "descriptions" referenced in this document could include but are not limited to written, oral, pictorial, and kinesthetic descriptions.
Suggested Content-Vocabulary in bold
ESS1-B: EARTH AND THE SOLAR SYSTEM *What are the predictable patterns caused by Earth's movement in the solar system?*
• The solar system consists of the sun and a collection of objects of varying sizes and conditions held in orbit around the sun by the **force of gravity.** • Earth and the **moon**, sun, and **planets** have predictable patterns of movement. These patterns explain many large-scale phenomena observed on Earth. o Gradual changes on the shape of the Earth's orbit, together with the **tilt** of the planet's spin axis, have altered the **intensity** and **distribution of sunlight** falling on Earth. These phenomena cause cycles of **climate change**. • Gravity holds Earth in orbit around the sun, and it holds the moon in orbit around Earth. o The pulls of gravity from the sun and the moon cause patterns of ocean **tides.** o The moon's monthly orbit around Earth, the relative positions of the sun, the moon, and the observer explain the observed **phases of the moon** • Even though the Earth's orbit is nearly circular, the intensity of sunlight on a given location varies as it orbits around the sun. o Earth's spin axis is tilted relative to the plane of its orbit, and the **seasons** are a result of that tilt. o The intensity of sunlight striking the Earth is greatest at the **equator**. o Seasonal variations in that intensity are greatest at the poles.

Disciplinary Core Ideas	Observable features of student performance
• Kepler's laws describe common features of the motions of orbiting objects, including their elliptical	*Students who understand the concepts are able to:* 1. Representation a. Students identify and describe the following relevant components in the given mathematical or computational representations of orbital motion: the trajectories of orbiting bodies, including planets,

paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4)	moons, or human-made spacecraft; each of which depicts a revolving body's eccentricity e = f/d, 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 or computational modeling a. Students use the given mathematical or computational representations of orbital motion to depict that the square of a revolving body's period of revolution 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 use the given mathematical or computational representation of Kepler's second law of planetary motion (an orbiting body sweeps out equal areas in equal time) to predict the relationship between the distance between an orbiting body and its star, and the object's orbital velocity (i.e., that the closer an orbiting body is to a star, the larger its orbital velocity will be). b. Students use the given mathematical or computational representation of Kepler's third law of planetary motion ($T^2 \propto R^3$, where T is the orbital period and R is the semi-major axis of the orbit) to predict how either the orbital distance or orbital period changes given a change in the other variable. c. Students use Newton's law of gravitation plus his third law of motion to predict how the acceleration of a planet towards the sun varies with its distance from the sun, and to argue qualitatively about how this relates to the observed orbits.

Crosscutting Concepts

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). (HS-ESS1-4)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.

Science and Engineering Practices
<u>Using Mathematical and Computational Thinking</u> 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 or computational representations of phenomena to describe explanations.

Grade Band Endpoint for ESS1-B
By the end of grade 12: Keplers's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to gravitational effects from, or collisions with, other objects in the solar system. Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation or the planet's axis of rotation, both occurring over tens to hundreds of thousands of year, have altered the intensity and distribution of sunlight falling on the earth. K-12 Endpoint Progression

Suggested projects
• Planetary Orbit Simulator - Explore each of Kepler's three laws with this interactive planetary orbit simulator. • Phun With PhET -Build your own solar system with this interactive Java applet from PhET. Total cosmic phun! • Kepler's Laws of Motion (Genesis) – Theme-based unit (pdf). Sample handout to accompany. • NGSS-HUB (project ideas)- link to various activities

Modifications to Content/Differentiation	
Priority	Enrichment
-To include suggestions regarding depth of coverage *-Minimum depth of coverage* -Kepler's Laws of Motion will be treated be addressed qualitatively unless students are mathematically capable. This section may be too much for freshmen and may need to be in the physics curriculum.	*-To include suggested extensions to investigations* *-Increased depth* -Kepler's Laws of Motion and the accompanying equations will be used.
Suggested Assessments	
• Traditional assessment: multiple choice and free response questions, or • The above project(s) using the eight science and engineering practice standards, or • A combination of traditional assessment with project, or • Other format of teacher's choice	

ESS1-C: THE HISTORY OF PLANET EARTH
(HS-ESS1-5), (HS-ESS1-6)
Compelling Question: *How do people reconstruct and date events in Earth's planetary history?*

Suggested Content-Vocabulary in bold

ESS1-C: THE HISTORY OF PLANET EARTH *How do people reconstruct and date events in Earth's planetary history?*

- Earth scientists use the **structure**, **sequence**, and properties of **rocks**, **sediments**, and **fossils**, as well as the locations of current and past **ocean basins**, **lakes**, and **rivers**, to reconstruct events in Earth's planetary history.
  - Analysis of rock formations and the fossil record are used to establish **relative ages**.
    - Rock layers have sometimes been rearranged by **tectonic forces**. These forces can lead to events that occur over hours to millions of years.
- Other objects in our solar system, such as **asteroids** and **meteorites**, have changed little over billions of years. Studying these help scientists deduce the solar system's age and history.

• Because many individual plant and animal species existed during known periods of time (e.g., dinosaurs), the location and certain types of fossils in the rock record can reveal the age of rocks and help **geologists** decipher the history of **landforms**.	
Disciplinary Core Ideas	Observable features of student performance
• 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. (HS-ESS1-5) • 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. (HS-ESS1-6) • ESS2.B: Plate Tectonics and Large-Scale System Interactions • Plate tectonics is the unifying theory that	*Students who understand the concepts are able to:* (HS-ESS1-5) 1. Identifying the given explanation and the supporting evidence a. Students identify the given explanation, which includes the following idea: that crustal materials of different ages are arranged on Earth's surface in a pattern that can be attributed to plate tectonic activity and formation of new rocks from magma rising where plates are moving apart. b. Students identify the given evidence to be evaluated. 2. Identifying any potential additional evidence that is relevant to the evaluation a. Students identify and describe additional relevant evidence (in the form of data, information, models, or other appropriate forms) that was not provided but is relevant to the explanation and to evaluating the given evidence, including: i. Measurement of the ratio of parent to daughter atoms produced during radioactive decay as a means for determining 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. The type and location of plate boundaries relative to the type, age, and location of crustal rocks 3. Evaluating and critiquing a. Students use their additional evidence to assess and evaluate the validity of the given evidence. b. Students evaluate the reliability, strengths, and weaknesses of the given evidence along with its ability to support logical and reasonable arguments about the motion of crustal plates. 4. Reasoning/synthesis

explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) (secondary) • 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.	a. Students describe how the following patterns observed from the evidence support the explanation about the ages of crustal rocks: i. The pattern of the continental crust being older than the oceanic crust; ii. The pattern that the oldest continental rocks are located at the center of continents, with the ages decreasing from their centers to their margin; and iii. The pattern that the ages of oceanic crust are greatest nearest the continents and decrease in age with proximity to the mid-ocean ridges. b. Students synthesize the relevant evidence to describe the relationship between the motion of continental plates and the patterns in the ages of crustal rocks, including that: i. At boundaries where plates are moving apart, such as mid-ocean ridges, material from the interior of the Earth must be emerging and forming new rocks with the youngest ages. ii. The regions furthest from the plate boundaries (continental centers) will have the oldest rocks because new crust is added to the edge of continents at places where plates are coming together, such as 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, such as subduction zones. (HS-ESS1-6) 5. Articulating the explanation of phenomena a. Students construct an account of Earth's formation and early history that includes that: i. Earth formed along with the rest of the solar system 4.6 billion years ago. ii. The early Earth was bombarded by impacts just as other objects in the solar system were bombarded. iii. Erosion and plate tectonics on Earth have destroyed much of the evidence of this bombardment, explaining the relative scarcity of impact craters on Earth. 6. Evidence a. Students include and describe the following evidence in their explanatory account: i. The age and composition of Earth's oldest rocks, lunar rocks, and meteorites as determined by

	radiometric dating; ii. The composition of solar system objects; iii. Observations of the size and distribution of impact craters on the surface of Earth and on the surfaces of solar system objects (e.g., the moon, Mercury, and Mars); and iv. The activity of plate tectonic processes, such as volcanism, and surface processes, such as erosion, operating on Earth. 7. <u>Reasoning</u> a. Students use reasoning to connect the evidence to construct the explanation of Earth's formation and early history, including that: i. Radiometric ages of lunar rocks, meteorites and the oldest Earth rocks point to 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 such as volcanism, plate tectonics, and erosion that have reshaped Earth's surface, and that this is why most of Earth's rocks are much younger than Earth itself.

Crosscutting Concepts

Patterns

- Empirical evidence is needed to identify patterns. (HS-ESS1-5)

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable.

Science and Engineering Practices

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. (HS-ESS1-5)

- Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.

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. (HS-ESS1-6)

- Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Connections to Engineering, Technology, and Applications of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-ESS1-6)
- Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (HS-ESS1-6)

Grade Band Endpoint for ESS1-C
By the end of grade 12:
Radioactive decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geological time. Continental rocks, which can be older than 4 billion years, are generally much older than rocks on the ocean floor, which are less than 200 million years old. Tectonic processes continually generate new ocean seafloor at ridges and destroy old seafloor at trenches. Although active geological processes, such as plate tectonics (link to ESS2.B) 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.
K-12 Endpoint Progression

Suggested Projects	
• Plate Tectonics Simulation- This is a simple to use Java based simulation from PhET, University of Boulder Colorado. In this simulation the learner can manipulate several variables related to the crust and then run experiments to produce data consistent with data from actual phenomena. • Fault Block Model Activity (*It's About Time*)- In this investigate your students will use our IAT Fault Block Model to experience what happens to energy from an earthquake. The students are asked to describe the causes of earthquakes, how they transmit energy, and how different types of seismic waves move. • A Model of Three Faults - Scientists have begun to estimate the locations and likelihoods of future damaging earthquakes. Sites of greatest hazard are being identified, and designing structures that will withstand the effects of earthquakes. ** The three preceding activities may be helpful for a few years but should be omitted once this is covered in middle school. The 9-12 focus on plate tectonics should be on radioactive decay within Earth's interior contributing to thermal convection in the mantle.* • Dating-Popcorn- How do geologists understand the Earth's history? In part, they measure the age of rocks and other natural materials by dating techniques. • Geologic Age-Decay of Zorkium- Radioisotopic dating and half-life determination activity • NGSS-HUB (project ideas)- link to various activities	
Modifications to Content/Differentiation	
Priority	**Enrichment**
-To include suggestions regarding depth of coverage *-Minimum depth of coverage* -Measurement of the ratio of parent to daughter atoms produced during radioactive decay as a means for determining the ages of rocks.	*-To include suggested extensions to investigations* *-Increased depth* -Specific nuclear decay sequences may be provided to emphasize conservation of energy and mass as well as nuclear isotopes.
Suggested Assessments	
• Traditional assessment: multiple choice and free response questions, or • The above project(s) using the eight science and engineering practice standards, or • A combination of traditional assessment with project, or • Other format of teacher's choice	

CORE IDEA: ESS2: Earth's Systems (14 class periods)	
How and why is Earth constantly changing? Earth's surface is a complex and dynamic set of interconnected systems—principally the geosphere, hydrosphere, atmosphere, and biosphere—that interact over a wide range of temporal and spatial scales. All of Earth's processes are the result of energy flowing and matter cycling within and among these systems. For example, the motion of tectonic plates is part of the cycles of convection in Earth's mantle, driven by outflowing heat and the downward pull of gravity, which result in the formation and changes of many features of Earth's land and undersea surface. Weather and climate are shaped by complex interactions involving sunlight, the ocean, the atmosphere, clouds, ice, land, and life forms. Earth's biosphere has changed the makeup of the geosphere, hydrosphere, and atmosphere over geological time; conversely, geological events and conditions have influenced the evolution of life on the planet. Water is essential to the dynamics of most earth systems, and it plays a significant role in shaping Earth's landscape.	
Component Ideas	**Performance Expectations**
ESS2-A: EARTH'S SYSTEMS Compelling question: How do Earth's major systems interact?	HS-ESS2-1, HS-ESS2-2, HS-ESS2-3, HS-ESS2-4
ESS2-B: PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS Compelling question: Why do the continents move, and what causes earthquakes and volcanoes?	HS-ESS2-1, HS-ESS1-5 and HS-ESS2-3
ESS2-C: THE ROLES OF WATER IN EARTH'S SURFACE PROCESSES Compelling question: How do the properties and movements of water shape Earth's surface and affect its systems?	HS-ESS2-5
ESS2-D: WEATHER AND CLIMATE Compelling question: What regulates weather and climate?	HS-ESS2-2, HS-ESS2-6, HS-ESS2-7, HS-ESS2-4 and HS-ESS3-6
ESS2-E: BIOGEOLOGY Compelling question: How do living organisms alters Earth's processes and structures?	HS-ESS2-7

NGSS Performance Expectations Students who demonstrate understanding can:

HS-ESS2-1

Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.

Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).

Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.

HS-ESS2-2

Analyze geoscience 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 feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.

HS-ESS2-3

Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.

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

HS-ESS2-4

Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.]

Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.

HS-ESS2-5

Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

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

HS-ESS2-6

Develop a quantitative model to describe the cycling of carbon among 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 (including humans), providing the foundation for living organisms.

Assessment Boundary: None for this Expectation.

HS-ESS2-7

Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

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 of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.

Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.

ESS2-A: EARTH'S SYSTEMS

(HS-ESS2-1, HS-ESS2-2, HS-ESS2-3, HS-ESS2-4)

Compelling Question*: How do Earth's major systems interact?*

Suggested Content – Vocabulary in bold

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- Student's support this understanding by using evidence and data from ;
  - **Deep probes** of the atmosphere, crust and long term studies.
  - **Seismic wave** for understanding the composition of the planet.
  - Reconstructions of historical changes in Earth's surface based on evidence
  - The planet's **magnetic field** it's influence on the atmosphere
- Develop an understanding of physical and chemical processes which lead to a model of Earth with:
  - a hot but solid **inner core**, a liquid **outer core** and a solid **mantle** and **crust.**
- The top part of the **mantle,** along with the **crust**, forms structures known as **tectonic plates**
- 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.
- The **geological record** shows that changes to **global** and **regional climate** can be caused by interactions among destructive and constructive changes from;
  - the **sun's** energy output or **Earth's orbit** affecting seasonal heating,
  - **tectonic** events which change landforms
  - **ocean circulation** and how there are changes in the exchange of energy and matter
  - **volcanic activity** which adds to the crustal rock mass
  - **glaciers** that erode and move rock
  - **vegetation** which filters the atmosphere seasonally, and erodes the lithosphere as well.
- How human activities speed up, augment or divert the changes in the planet.
- These changes can occur on a variety of time scales from sudden (e.g., **volcanic ash clouds**) to intermediate (**ice ages**) to very long-term tectonic cycles.

Disciplinary Core Ideas	Observable features of student performance
-Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. HS-ESS2-1, HS-ESS2-2 • Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. HS-ESS2-3/ ESS2.A - The geological record shows that changes to global and regional climate can be caused by interactions among changes	HS-ESS2-1 1. Components of the model that includes: a. Students use evidence to develop a model in which they identify and describe the following components: i. Descriptions and locations of specific continental features and specific ocean-floor features. ii. A geographic scale, showing the relative sizes/extents of continental and/or ocean floor features. iii. Internal processes (such as volcanism and tectonic uplift) and surface processes (such as weathering and erosion); and iv. A temporal scale showing the relative times over which processes act to produce continental and/or ocean-floor features 2. Relationships a. In the model, students describe the relationships between components, including: i. Specific internal processes, mainly volcanism, mountain building or tectonic uplift, are identified as causal agents in building up Earth's surface over time. ii. Specific surface processes, mainly weathering and erosion, are identified as causal agents in wearing down Earth's surface over time. iii. Interactions and feedbacks between processes are identified (e.g., mountain-building changes weather patterns that then change the rate of erosion of mountains). iv. The rate at which the features change is related to the time scale on which the processes operate. Features that form or change slowly due to processes that act on long time scales (e.g., continental positions due to plate drift) and features that form or change rapidly due to processes that act on short time scales (e.g., volcanic eruptions) are identified.

in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. HS-ESS2-4/ ESS2.A -Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (ESS2.B Grade 8 GBE) HS-ESS2-1/ ESS2.B 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	3. Connections a. Students use the model to illustrate the relationship between i. the formation of continental and ocean floor features and ii. Earth's internal and surface processes operating on different temporal or spatial scales. HS-ESS2-2 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. b. Students describe what each data set represents. 2. Identifying relationships a. Students use tools, technologies, and/or models to analyze the data and identify and describe relationships in the datasets, including: i. The relationships between the 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 if present. 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 a particular unanticipated or unintended effect of a selected technology on Earth's systems if present. c. Students include a statement regarding how variation or uncertainty in the data (e.g., limitations, accuracy, any bias in the data resulting from choice of sample, scale, instrumentation, etc.) may affect the interpretation of the data.

convection. Plate tectonics can be viewed as the surface expression of mantle convection. HS-ESS2-3/ ESS2.B • Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary) HS-ESS2-4/ ESS1.B • The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden	HS-ESS2-3 1. Components of the model a. Students develop a model (i.e., graphical, verbal, or mathematical) in which they identify and describe the components based on both seismic and magnetic evidence (e.g., the 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. The plate activity in the outer part of the geosphere; iii. Radioactive decay and residual thermal energy from the formation of the Earth as a source of energy; iv. The loss of heat at the surface of the earth as an output of energy; and v. The process of convection that causes hot matter to rise (move away from the center) and cool matter to fall (move toward the center). 2. Relationships a. Students describe the relationships between components in the model, including: i. Energy released by radioactive decay in the Earth's crust and mantle and residual thermal energy from the formation of the Earth 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 mantle and the sinking of cold, dense crust back into the mantle 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 material can be integrated into the crust, forming new rock. 3. Connections a. Students use the model to describe the cycling of matter by thermal convection in Earth's

(e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. HS-ESS2-4/ ESS2.A • 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 reradiation into space. HS-ESS2-2 HS-ESS2-4/ ESS2.D	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 (e.g., seafloor exploration of changes in the direction of Earth's magnetic field); iii. The radial layers determined by density in the interior of Earth; and iv. The addition of a significant amount of thermal energy released by radioactive decay in Earth's crust and mantle. HS-ESS2-4 1. Components of the model: a. From the given model, students identify and describe the components of the model relevant for their mechanistic descriptions. Given models include 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 redistribution of energy. Factors are derived from the following list: 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 composition (including amount of 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. From the given model, students identify the relevant different time scales on which the factors operate. 2. Relationships a. Students identify and describe the relationships between components of the given model, and organize the factors from the given model into three groups: i. Those that affect the input of energy;

	ii. Those that affect the output of energy; and iii. Those that affect the storage and redistribution of energy b. Students describe the relationships between components of the model as either causal or correlational. 3. <u>Connections</u> a. Students use the given model to provide a mechanistic account of the relationship between energy flow in Earth's systems and changes in climate, including: i. The 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 of the competing factors in changing the climate.

Crosscutting Concepts

Stability and Change

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Feedback (negative or positive) can stabilize or destabilize a system.
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Energy and Matter

- Energy drives the cycling of matter within and between systems.

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

<u>Connections to Engineering, Technology, and Applications of Science</u>

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.

Interdependence of Science, Engineering, and Technology

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.

Science and Engineering Practices

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 the relationships between systems or between components of a system. (HS-ESS2-1, HS-ESS2-3)
    - Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4)

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. (HS-ESS2-2)

Connections to Nature of Science

- Scientific Knowledge is Based on Empirical Evidence
    - Science knowledge is based on empirical evidence.
    - Science disciplines share common rules of evidence used to evaluate explanations about natural systems.
    - Science includes the process of coordinating patterns of evidence with current theory.
    - Science arguments are strengthened by multiple lines of evidence supporting a single explanation.

Grade Band Endpoints for ESS2A

By the end of grade 12:

Feedback effects exist within and among Earth's systems.

K-12 Endpoint Progression

Suggested Projects

- Model how energy is introduced into the planet and properly show how that energy affects changes in the geology or environment either in short term or long term results.
- Model of Faults – Tectonic plate modeling
- Dating Popcorn – popping corn to help model radioactive decay
- Earth Caching - Geo Caching activity
- Earth Gravestone Project- measuring weathering of marble
- Magnets at the Earth's Core- classroom modeling of shifts in magnetic north and south
- Sink Holes in a Cup – modeling ground water erosion creating empty space
- Pulse of the Classroom – modeling vibrations for tracking earth quakes

Modifications to Content/Differentiation

Priority	Enrichment
- *To include suggestions regarding depth of coverage* - *Minimum depth of coverage* - How the planet is heated internally - Where the magnetic field comes from and benefits - Where energy is a factor into the surface conditions (weather) and circulation of air, water and moisture on the planet. - Understanding climate zones around the planet.	- *To include suggested extensions to investigations* - *Increased depth* - Density of air or water column affecting convection patterns - Predicting weather due to changes in patterns and energy. - How changes to composition of the atmosphere have affected heat capacity, weather and precipitation patterns.

Suggested Assessments

- Traditional assessment: multiple choice and free response questions, or
- The above project(s) using the eight science and engineering practice standards, or
- A combination of traditional assessment with project, or
- Other format of teacher's choice

ESS2-B: Plate Tectonics and Large –Scale System Interactions (HS-ESS1-5, HS-ESS2-1, HS-ESS2-3) Compelling Question*: Why do the continents move, and what causes earthquakes and volcanoes?*	
Suggested Content– Vocabulary in bold	
○ Internal processes germane to the planet which cause the movement of and development of **tectonic plates** and produces the **magnetic field** around the planet. ○ Re-Construction and understanding of the layers of the planet based on evidence collected ○ How **plates** move and change surface of planet and position of features of the planet due to constructive (Sea floor spreading, volcanism) or destructive, subduction. ○ How **mountains** are built due to lifting and plate interaction or torn down due erosional forces. ○ **Volcanism** the source of growing magma, the point of origin due to subduction how land masses evolve as volcanoes age. ○ **Hot spots** and their importance either in island chain development or the potential for catastrophe in regards to Yellowstone. ○ Movement and change of magnetic field as presented due to field lines and changes in polarity discovered in oceanic rock. ○ **Radioactive dating** and how its development has helped us understand how old the planet is, when important eras on the planet occurred and the age of species that have existed. ○ **Earthquakes** and how they develop due to plate on plate interactions which build up stress and release either as short tremors or large area wide catastrophes.	
Disciplinary Core Ideas	**Observable features of student performance**
• Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for	HS-ESS1-5 1. Identifying the given explanation and the supporting evidence a. Students identify the given explanation, which includes the following idea: that crustal materials i. of different ages are arranged on Earth's surface in a pattern that can be attributed to plate ii. tectonic activity and formation of new rocks from magma rising where plates are moving apart.

understanding its geologic history. (ESS2.B Grade 8 GBE) (secondary) HS-ESS1-5/ ESS2.B 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. (secondary) HS-ESS1-5 • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. HS-ESS2-1/ ESS2.A: • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most	b. Students identify the given evidence to be evaluated. 2. Identifying any potential additional evidence that is relevant to the evaluation a. Students identify and describe additional relevant evidence (in the form of data, information, models, or other appropriate forms) that was not provided but is relevant to the explanation and to evaluating the given evidence, including: i. Measurement of the ratio of parent to daughter atoms produced during radioactive decay as a means for determining 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. The type and location of plate boundaries relative to the type, age, and location of crustal rocks. 3. Evaluating and critiquing a. Students use their additional evidence to assess and evaluate the validity of the given evidence. b. Students evaluate the reliability, strengths, and weaknesses of the given evidence along with its ability to support logical and reasonable arguments about the motion of crustal plates. 4. Reasoning/synthesis a. Students describe how the following patterns observed from the evidence support the explanation about the ages of crustal rocks: i. The pattern of the continental crust being older than the oceanic crust ii. The pattern that the oldest continental rocks are located at the center of continents with the ages decreasing from their centers to their margin; and iii. The pattern that the ages of oceanic crust are greatest nearest the continents and decrease in age with proximity to the mid-ocean ridges. b. Students synthesize the relevant evidence to describe the relationship between the motion of continental plates and the patterns in the ages of crustal rocks, including that: i. At boundaries where plates are moving apart, such as mid-ocean ridges, material from the interior of the Earth must be emerging and forming new rocks with the youngest ages. ii. The regions furthest from the plate boundaries (continental centers) will have the oldest rocks because new crust is added to the edge of continents at places where plates are coming

continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (ESS2.B Grade 8 GBE) HS-ESS2-1/ ESS2.B: • Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. HS-ESS2-3/ ESS2.A • The radioactive decay of	together, such as 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, such as subduction zones. HS-ESS2-1 1. Components of the model a. Students use evidence to develop a model in which they identify and describe the following components: i. Descriptions and locations of specific continental features and specific ocean-floor features; ii. A geographic scale, showing the relative sizes/extents of continental and/or ocean floor features; iii. Internal processes (such as volcanism and tectonic uplift) and surface processes (such as weathering and erosion); and iv. A temporal scale showing the relative times over which processes act to produce continental and/or ocean-floor features. 2. Relationships a. In the model, students describe the relationships between components, including: i. Specific internal processes, mainly volcanism, mountain building or tectonic uplift, are identified as causal agents in building up Earth's surface over time. ii. Specific surface processes, mainly weathering and erosion, are identified as causal agents in wearing down Earth's surface over time. iii. Interactions and feedbacks between processes are identified (e.g., mountain-building changes weather patterns that then change the rate of erosion of mountains). iv. The rate at which the features change is related to the time scale on which the processes operate. Features that form or change slowly due to processes that act on long time scales (e.g., continental positions due to plate drift) and features that form or change rapidly due to processes that act on short time scales (e.g., volcanic eruptions) are identified. 3. Connections a. Students use the model to illustrate the relationship between 1) the formation of continental and ocean floor features and 2) Earth's internal and surface processes operating on different temporal

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. HS-ESS2-3/ ESS2.B	or spatial scales. HS-ESS2-3 1. Components of the model a. Students develop a model (i.e., graphical, verbal, or mathematical) in which they identify and describe the components based on both seismic and magnetic evidence (e.g., the 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. The plate activity in the outer part of the geosphere; iii. Radioactive decay and residual thermal energy from the formation of the Earth as a source of energy; iv. The loss of heat at the surface of the earth as an output of energy; and v. The process of convection that causes hot matter to rise (move away from the center) and cool matter to fall (move toward the center). 2. Relationships a. Students describe the relationships between components in the model, including: i. Energy released by radioactive decay in the Earth's crust and mantle and residual thermal energy from the formation of the Earth 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 mantle and the sinking of cold, dense crust back into the mantle 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 material can be integrated into the crust, forming new rock. 3. Connections a. Students use the 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 (e.g., seafloor exploration of changes in the direction of Earth's magnetic field); iii. The radial layers determined by density in the interior of Earth; and iv. The addition of a significant amount of thermal energy released by radioactive decay in Earth's crust and mantle.

Crosscutting Concepts

Patterns

- Empirical evidence is needed to identify patterns

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.

Energy and Matter

- Energy drives the cycling of matter within and between systems.

<u>Interdependence of Science, Engineering, and Technology</u>

- 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.

Science and Engineering Practices

Engaging in Argument from Evidence

- Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.

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 the relationships between systems or between components of a system.

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based on empirical evidence.
- Science disciplines share common rules of evidence used to evaluate explanations about natural systems.
- Science includes the process of coordinating patterns of evidence with current theory.

Grade Band Endpoints: By the end of grade 12

By the end of grade 12:

Radioactive decay within Earth's interior contributes to thermal convection in the mantle.

K-12 Endpoint Progression

Suggested Projects

- Modeling of crust layers, proper plate boundaries and movement along with how this movement plays in the development and destruction of surface features.
- Model of Faults – Tectonic plate modeling
- Dating Popcorn – popping corn to help model radioactive decay
- Earth Caching - Geo Caching activity
- Earth Gravestone Project- measuring weathering of marble
- Magnets at the Earth's Core- classroom modeling of shifts in magnetic north and south
- Sink Holes in a Cup – modeling ground water erosion creating empty space
- Pulse of the Classroom – modeling vibrations for tracking earth quakes
- Glacier Slide—modeling glacial movement due to freeze/thaw process
- ID Watersheds – investigating potential watersheds in town area using topographical maps

Modifications to Content/Differentiation	
Priority	Enrichment
-To include suggestions regarding depth of coverage *-Minimum depth of coverage* -Tectonic plates - rock density - continental land forms (mountains, volcanoes) - fault lines - Volcanism - radioactivity	*-To include suggested extensions to investigations* *-Increased depth* - Seismic monitoring - Hot spots - Half-life calculations - Volcanic monitoring

Suggested Assessments
• Traditional assessment: multiple choice and free response questions, or • The above project(s) using the eight science and engineering practice standards, or • A combination of traditional assessment with project, or • Other format of teacher's choice

<table>
<tr><td colspan="2">ESS2.C: THE ROLES OF WATER IN EARTH'S SURFACE PROCESSES
(HS-ESS2-5)
Compelling Question: How do the properties and movements of water shape Earth's surface and affect its systems?</td></tr>
<tr><td colspan="2">Suggested Content– Vocabulary in Bold</td></tr>
<tr><td colspan="2">ESS2.C: The Roles of Water in Earth's Surface Properties
● 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 including;
○ water's exceptional capacity to absorb, store, and release large amounts of energy;
○ transmit sunlight; thermal absorption which varies seasonally and longitudinally affecting climate and ecosystems
○ expand upon freezing; frost wedging as a destructive force that erodes mountains changing geologic features
○ erosion and deposition of materials that shapes landforms such as canyons, rivers, tributaries, water tables, rills, creeps and rock peeling
○ lower the viscosities and melting points of rocks as a factor to consider in the Bowden reaction series for crystallization of rock or in metmorphosizing rock into a different mineral composition.</td></tr>
<tr><td><u>Disciplinary Core Ideas</u></td><td><u>Observable features of student performance</u></td></tr>
<tr><td>● 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,</td><td>HS-ESS2-5
1. <u>Identifying the phenomenon to be investigated</u>
a. Students describe the phenomenon under investigation, which includes the following idea: a connection between the properties of water and its effects on Earth materials and surface processes.

2. <u>Identifying the evidence to answer this question</u>
a. Students develop an investigation plan and describe the data that will be collected and the evidence to be derived from the data, including:
i. Properties of water, including:</td></tr>
</table>

transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. [HS-ESS2-5/ ESS2.C]	a) The heat capacity of water; b) The density of water in its solid and liquid states; and c) The polar nature of the water molecule due to its molecular structure. ii. The effect of the properties of water on energy transfer that causes the patterns of temperature, the movement of air, and the movement and availability of water at Earth's surface. iii. Mechanical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes. Examples can include: a) Stream transportation and deposition using a stream table, which can be used to infer the ability of water to transport and deposit materials; b) Erosion using variations in soil moisture content, which can be used to infer the ability of water to prevent or facilitate movement of Earth materials; and c) The expansion of water as it freezes, which can be used to infer the ability of water to break rocks into smaller pieces. iv. Chemical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes. Examples can include: a) The solubility of different materials in water, which can be used to infer chemical weathering and recrystallization; b) The reaction of iron to rust in water, which can be used to infer the role of water in chemical weathering; c) Data illustrating that water lowers the melting temperature of most solids, which can be used to infer melt generation; and d) Data illustrating that water decreases the viscosity of melted rock, affecting the movement of magma and volcanic eruptions. b. In their investigation plan, students describe how the data collected will be relevant to determining the effect of water on Earth materials and surface processes. 3. <u>Planning for the Investigation</u> a. In their investigation plan, students include a means to indicate or measure the predicted effect of water on Earth's materials or surface processes. Examples include: i. The role of the heat capacity of water to affect the temperature, movement of air and movement of water at the Earth's surface;

	ii. The role of flowing water to pick up, move and deposit sediment; iii. The role of the polarity of water (through cohesion) to prevent or facilitate erosion; iv. The role of the changing density of water (depending on physical state) to facilitate the breakdown of rock; v. The role of the polarity of water in facilitating the dissolution of Earth materials; vi. Water as a component in chemical reactions that change Earth materials; and vii. The role of the polarity of water in changing the melting temperature and viscosity of rocks. b. In the plan, students state whether the investigation will be conducted individually or collaboratively. 4. <u>Collecting the data</u> a. Students collect and record measurements or indications of the predicted effect of a property of water on Earth's materials or surface. 5. <u>Refining the design</u> a. Students evaluate the accuracy and precision of the collected data. b. Students evaluate whether the data can be used to infer the effect of water on processes in the natural world. c. If necessary, students refine the plan to produce more accurate and precise data.

Crosscutting Concepts

Structure and Function

- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Science and Engineering Practices

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, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Grade Band Endpoints
By the end of grade 12: The planet's dynamics are greatly influenced by water's unique chemical and physical properties. K-12 Endpoint Progression

Suggested Projects
• Erosion/stream bed modeling • Soil Color- investigate soil color relating to composition • Sea Salinity- investigate how salinity relates to temperatures • Fresh vs Salt Water – compare and investigate properties of fresh vs salt water • Make a Cave – model cave/empty space development. • Explore Porosity- explore how empty space affect liquid carrying capacity of soil.

Modifications to Content/Differentiation	
Priority	Enrichment
-To include suggestions regarding depth of coverage *- Minimum depth of coverage* - Properties of water - Erosional features of streams - Land features created by water (caves, sinkholes, waterfalls, oxbow lakes).	*-To include suggested extensions to investigations* *-Increased depth* - Potential to expand upon and investigate how salinity and/or pH changes the properties of water and changes the capacity of water to erode materials, thermal/freeze capacity, effects on biologicals.

Suggested Assessments
• Traditional assessment: multiple choice and free response questions, or • The above project(s) using the eight science and engineering practice standards, or • A combination of traditional assessment with project, or • Other format of teacher's choice

ESS2-D: WEATHER AND CLIMATE (HS-ESS2-2, HS-ESS2-4, HS-ESS2-6, HS-ESS2-7, HS-ESS3-6) Compelling Question*: What regulates weather and climate?*
Suggested Content– Vocabulary in bold
ESS2-D: WEATHER AND CLIMATE: *What regulates weather and climate?* • The foundation for **Earth's global climate system** 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. o **Climate change** can occur when certain parts of Earth's systems are altered. o **Geological** evidence indicates that past **climate changes** were either sudden changes caused by alterations in the atmosphere; longer term changes (e.g., ice ages) due to variations in **solar output, Earth's orbit,** or the orientation of its axis; or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen. o The time scales of these changes varied from a few to millions of years. Changes in the atmosphere due to human activity have increase carbon dioxide concentrations and thus affect climate. o Incorporate knowledge of physical and chemical processes and of the interactions of relevant systems to fit past climate variations. o Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise 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 the biosphere. o Outcomes depend on human behaviors as well as on natural factors that involve complex feedbacks among Earth's systems.

Disciplinary Core Ideas	Observable features of student performance
• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. HS-ESS2-2 / ESS2.A • The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. HS-ESS2-4/ ESS2.A • Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the	HS-ESS2-2 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. b. Students describe what each data set represents. 2. Identifying relationships a. Students use tools, technologies, and/or models to analyze the data and identify and describe relationships in the datasets, including: i. The relationships between the 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 if present. 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 a particular unanticipated or unintended effect of a selected technology on Earth's systems if present. c. Students include a statement regarding how variation or uncertainty in the data (e.g., limitations, accuracy, any bias in the data resulting from choice of sample, scale, instrumentation, etc.) may affect the interpretation of the data. HS-ESS2-4 1. Components of the model: a. From the given model, students identify and describe the components of the model relevant for their mechanistic descriptions. Given models include 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

intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary) HS-ESS2-4/ ESS1.B • 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 reradiation into space. HS-ESS2-2 / 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. HS-ESS2-6/ ESS2.D • Gradual atmospheric changes were due to plants	redistribution of energy. Factors are derived from the following list: 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 composition (including amount of 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. From the given model, students identify the relevant different time scales on which the factors operate. 2. Relationships a. Students identify and describe the relationships between components of the given model, and organize the factors from the given model into three groups: i. Those that affect the input of energy; ii. Those that affect the output of energy; and iii. Those that affect the storage and redistribution of energy b. Students describe the relationships between components of the model as either causal or correlational. 3. Connections a. Students use the given model to provide a mechanistic account of the relationship between energy flow in Earth's systems and changes in climate, including: i. The 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 of the competing factors in changing the climate.

and other organisms that captured carbon dioxide and released oxygen. HS-ESS2-7/ ESS2.D • The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it. HS-ESS2-7/ ESS2.E • 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. (secondary) HS-ESS3-6/ ESS2.D • Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are	HS-ESS2-6 1. Components of the model a. Students use evidence to develop a model in which they: i. Identify the relative concentrations of carbon present in the hydrosphere, atmosphere, geosphere and biosphere; and ii. Represent carbon cycling from one sphere to another. 2. Relationships a. In the model, students represent and describe the following relationships between components of the system, including: i. The biogeochemical cycles that occur as carbon flows from one sphere to another; ii. The relative amount of and the rate at which carbon is transferred between spheres; iii. The capture of carbon dioxide by plants; and iv. The increase in carbon dioxide concentration in the atmosphere due to human activity and the effect on climate. 3. Connections a. Students use the model to explicitly identify the conservation of matter as carbon cycles through various components of Earth's systems. b. Students identify the limitations of the model in accounting for all of Earth's carbon. HS-ESS2-7 1. Developing the claim a. Students develop a claim, which includes the following idea: that there is simultaneous coevolution of Earth's systems and life on Earth. This claim is supported by generalizing from multiple sources of evidence. 2. Identifying scientific evidence a. Students identify and describe evidence supporting the claim, including: i. Scientific explanations about the composition of Earth's atmosphere shortly after its formation; ii. Current atmospheric composition;

modified in response to human activities. HS-ESS3-6/ ESS3.D	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; v. In the context of the selected example(s), other evidence that changes in the biosphere affect other Earth systems. 3. Evaluating and critiquing a. Students evaluate the evidence and include the following in their evaluation: i. A statement regarding how variation or uncertainty in the data (e.g., limitations, low signal-to-noise ratio, collection bias, etc.) may affect the usefulness of the data as sources of evidence; and ii. The ability of the data to be used to determine causal or correlational effects between changes in the biosphere and changes in Earth's other systems. 4. Reasoning and synthesis a. Students use at least two examples to construct oral and written logical arguments. The examples: i. Include 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 weathering due to an oxidizing atmosphere and the evolution of animal life that depends on oxygen for respiration; and ii. Identify causal links and feedback mechanisms between changes in the biosphere and changes in Earth's other systems. HS-ESS3-6 1. Representation a. Students identify and describe the relevant components of each of the Earth systems modeled in the given computational representation, including system boundaries, initial conditions, inputs and outputs, and relationships that determine the interaction (e.g., the relationship between atmospheric CO_2 and production of photosynthetic biomass and ocean acidification). 2. Computational modeling a. Students use the given computational representation of Earth systems to illustrate 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 use evidence from the computational representation to describe how human activity could affect the relationships between the Earth's systems under consideration.

Crosscutting Concepts

Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system.
- Much of science deals with constructing explanations of how things change and how they remain stable.

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Energy and Matter (HS-ESS2-6)

- The total amount of energy and matter in closed systems is conserved.

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.

Connections to Engineering, Technology, and Applications of Science

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. (HS-ESS2-2)

Science and Engineering Practices

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.

Scientific Knowledge is Based on Empirical Evidence

- Science arguments are strengthened by multiple lines of evidence supporting a single explanation.

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 to provide mechanistic accounts of phenomena.
  - Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

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.

Using Mathematics and Computational Thinking from ESS3?

- 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;
  - 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.

<u>Connections to Nature of Science</u>

Scientific Knowledge is Based on Empirical Evidence

- Science arguments are strengthened by multiple lines of evidence supporting a single explanation.

Grade Band Endpoints

By the end of grade 12:

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

K-12 Endpoint Progression

Suggested Projects
• Monitoring and predicting weather. • Monitor Hurricanes – investigate formation of hurricane • Energy Use – model use of soil as insulator and how colors affect differential surface heating • Ocean Conveyor – Model water convection currents and relate to global oceanic current patterns • Your Own El Nino- develop model of mixing which occurs in oceans building energy for the El Nino effect.

Modifications to Content/Differentiation	
Priority	Enrichment
- *To include suggestions regarding depth of coverage* - *Minimum depth of coverage* - Understanding the components of weather. - How does the Sun create changes in weather and ocean patterns? - What are the major climate zones of the planet?	- *To include suggested extensions to investigations* - *Increased depth* - Predict weather - Potential to investigate micro climates - Potential to investigate extreme climates and seasonal swings of the planet.

Suggested Assessments
• Traditional assessment: multiple choice and free response questions, or • The above project(s) using the eight science and engineering practice standards, or • A combination of traditional assessment with project, or • Other format of teacher's choice

ESS2-E: BIOGEOLOGY (HS-ESS2-7) Compelling Question: *How do living organisms alter Earth's processes and structures?*	
Suggested Content– Vocabulary in bold	
ESS2-E: BIOGEOLOGY: *How do living organisms alter Earth's processes and structures?* • 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. • How life has and will impact the surface of the planet through time either from the development of forests, diatoms as contributors to the oxygen content of the planet or as humans change the planet through use of resources for energy or acquisition of resources through deforestation, farming or mining.. • How life has long term and short term impacts on **weather, climate, geology, ecosystems**. • How those changes have impacted **human behavior and practice** along with **migratory patterns, eating habits and habitat demands** of other species.	
Disciplinary Core Ideas	Observable features of student performance
• Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. HS-ESS2-7 / ESS2.D • The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it.	HS-ESS2-7 1. Developing the claim a. Students develop a claim, which includes the following idea: that there is simultaneous coevolution of Earth's systems and life on Earth. This claim is supported by generalizing from multiple sources of evidence. 2. Identifying scientific evidence a. Students identify and describe evidence supporting the claim, including: i. Scientific explanations about the composition of Earth's atmosphere shortly after its formation; ii. Current atmospheric composition; 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;

HS-ESS2-7 /ESS2.E	v. In the context of the selected example(s), other evidence that changes in the biosphere affect other Earth systems. 3. <u>Evaluating and critiquing</u> a. Students evaluate the evidence and include the following in their evaluation: i. A statement regarding how variation or uncertainty in the data (e.g., limitations, low signal-to-noise ratio, collection bias, etc.) may affect the usefulness of the data as sources of evidence; and ii. The ability of the data to be used to determine causal or correlational effects between changes in the biosphere and changes in Earth's other systems. 4. <u>Reasoning and synthesis</u> a. Students use at least two examples to construct oral and written logical arguments. The examples: i. Include 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 weathering due to an oxidizing atmosphere and the evolution of animal life that depends on oxygen for respiration; and ii. Identify causal links and feedback mechanisms between changes in the biosphere and changes in Earth's other systems.

Crosscutting Concepts

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable.

Science and Engineering Practices

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

Grade Band Endpoints
By the end of grade 12 The biosphere and Earth's other systems have many interconnections that cause a continual coevolution of Earth's surface and life on it. K-12 Endpoint Progression

Suggested Projects
• Conservation in Action- Conservation act research • A Bit of Engineering – Develop a tool to best core out a sample of sea bed • Traveling Nitrogen – Follow the flow of nitrogen through an ecosystem • Know your Energy Cost – Track and develop a spreadsheet of energy cost of electrical devices in student's house. • Acid-Mine Drainage – Series of investigations for affects of acids on ground water penetration • Exploring Change with Global Information Systems – Using current and past GIS images to understand changes in land use/formations • Bird Seed Mining- Use of birdseed to model cost of mining vs materials gained.

Modifications to Content/Differentiation	
Priority	Enrichment
-To include suggestions regarding depth of coverage *- Minimum depth of coverage.* - Long term vs short term affects in environment - Human impacts on environment - Loss of habitat and impacts on organisms	*-To include suggested extensions to investigations* *- Increased depth* - Development of sustainable living - Debate on potential for future existence of planet - Debate on shifts needed in consumerism and resource use

Suggested Assessments
• Traditional assessment: multiple choice and free response questions, or • The above project(s) using the eight science and engineering practice standards, or • A combination of traditional assessment with project, or • Other format of teacher's choice

CORE IDEA: ESS 3: Earth and Human Activity (20 class periods)	
How do Earth's surface processes and human activities affect each other? Earth's surface processes affect and are affected by human activities. Humans depend on all of the planet's systems for a variety of resources, some of which are renewable or replaceable and some of which are not. Natural hazards and other geological events can significantly alter human populations and activities. Human activities, in turn, can contribute to the frequency and intensity of some natural hazards. Indeed, humans have become one of the most significant agents of change in Earth's surface systems. In particular, it has been shown that climate change—which could have large consequences for all of Earth's surface systems, including the biosphere—is driven not only by natural effects, but also by human activities. Sustaining the biosphere will require detailed knowledge and modeling of the factors that affect climate, coupled with the responsible management of natural resources. (excerpt from Framework page 190-191)	
Component Ideas	**Performance Expectations**
ESS3-A: NATURAL RESOURCES Compelling question: How do humans depend on Earth's resources*?*	HS-ESS3-1 and HS-ESS3-2
ESS3-B: NATURAL HAZARDS Compelling question: *How do natural hazards affect individuals and societies?*	HS-ESS3-1
ESS3-C: HUMAN IMPACTS ON EARTH SYSTEMS Compelling question: *How do humans change the planet?*	HS-ESS3-3 and HS-ESS3-4
ESS3-D: GLOBAL CLIMATE CHANGE Compelling question: *How do people model and predict the effects of human activities on Earth's climate?*	HS-ESS3-5 and HS-ESS3-6

Student Learning Objectives (NGSS Performance Expectations) Students who demonstrate understanding can:
[HS-ESS3-1](#) **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.** **Clarification Statement:** Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised. [HS-ESS3-2](#) **Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*** **Clarification Statement:** Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen. [HS-ESS3-3](#) **Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.** **Clarification Statement:** Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning. **Assessment Boundary**: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations. [HS-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).

HS-ESS3-5

Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth 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).

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

HS-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. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.

Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.

ESS3-A: NATURAL RESOURCES and **ESS3-B: NATURAL HAZARDS** (can be combined and taught together)

(HS-ESS3-1 and HS-ESS3-2)

Compelling Questions: ***How do humans depend on Earth's resources? How do natural hazards affect individuals and societies?***

Suggested Content– Vocabulary in bold

ESS3.A: NATURAL RESOURCES: *How do humans depend on Earth's resources?*

- **Renewable** and **non-renewable** resources
  - Definitions and examples
  - Formation theory, uneven distribution, and supply estimated
- Humans depend on **Earth's resources**

- Personal/residential
- Industry/electricity/transportation
- Agriculture

- Relationship between human population distribution/growth and availability of resources
  - Human population distribution/spread guided and limited by the availability **natural resources**
  - Human **population growth/growth rate** limited and promoted by the availability of natural resources
  - Humans increasing demands cause some of the resources to become scarce and more valued
- All forms of **resource extraction** and usage have associated costs and benefits:
  - Economic **costs** and **benefits**
  - Social costs and benefits
  - Environmental costs and benefits
  - Geopolitical costs and benefits
- New **technologies** and **regulations** can change the balance of the cost and benefit factors
  - Examples of roles of new technologies
  - Examples of roles of regulations
  - Future needs of new technologies and regulations to sustain the growing human population

ESS3.B: NATURAL HAZARDS: *How do natural hazards affect individuals and societies?*

- Some natural processes can adversely affect humans
  - Earthquakes, **tsunamis**, volcanic eruptions, severe weather, floods and coastal **erosion**
  - Observation and knowledge of historical events help people prepare for and respond to **natural hazards**
- Steps which can be used to reduce the impacts of natural hazards
  - Examples of how to respond to natural hazards, such as earthquakes, floods, etc.

- Some natural hazards have become predictable, and others are not yet.
  - Examples of the predictable, such as volcanic eruption, severe **weather**
  - Examples of the unpredictable, such as earthquakes
  - Science and technology help study natural hazards, for example, **satellites monitoring** is used to study weather pattern.
- Natural hazards and other geological events have shaped the course of human history, altering human population size and **migration pattern**.
  - Examples of natural hazards which have impacted population size and migration pattern
  - Natural hazards, which can be local, regional or global in origin, can have distant impacts due to interconnectedness.
  - Human activities can contribute to the frequency and intensity of some natural hazards
  - Natural hazards' impacts increases with the increase of **population density**

Disciplinary Core Ideas	Observable features of student performance
• Resource availability has guided the development of human society. (HS-ESS3-1) • 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. (HS-ESS3-2)	HS-ESS3-1 1. Articulating the explanation of phenomena a. Students construct an explanation that includes: i. Specific cause and effect relationships between environmental factors (natural hazards, changes in climate, and the availability of natural resources) and features of human societies including population size and migration patterns; and ii. That technology in modern civilization has mitigated some of the effects of natural hazards, climate, and the availability of natural resources on human activity. 2. Evidence a. Students identify and describe the evidence to construct their 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. Changes in climate that affect human activity (e.g., agriculture) and human populations, and that can drive mass migrations; iii. Features of human societies that have been affected by the availability of natural resources; and

• Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-1) • 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. **(ETS1.B)** (ETS: Engineering, Technology, and Applications of Science)	iv. Evidence of the dependence of human populations on technological systems to acquire natural resources and to modify physical settings. b. Students use a variety of valid and reliable sources for the evidence, potentially including theories, simulations, peer review, or students' own investigations. 3. Reasoning a. Students use reasoning that connects the evidence, along with 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, to describe: i. The effect of natural hazards, changes in climate, and the availability of natural resources on features of human societies, including population size and migration patterns; and ii. How technology has changed the cause and effect relationship between the development of human society and natural hazards, climate, and natural resources. b. Students describe reasoning for how the evidence allows for the distinction between causal and correlational relationships between environmental factors and human activity. HS-ESS3-2 4. Supported claims a. Students describe the nature of the problem each design solution addresses. b. Students identify the solution that has the most preferred cost-benefit ratios. 5. Identifying scientific evidence a. Students identify evidence for the design solutions, including: i. Societal needs for that energy or mineral resource; ii. The cost of extracting or developing the energy reserve or mineral resource; iii. The costs and benefits of the given design solutions; and iv. The feasibility, costs, and benefits of recycling or reusing the mineral resource, if applicable. 6. Evaluation and critique a. Students evaluate the given design solutions, including: i. The relative strengths of the given design solutions, based on associated economic, environmental, and geopolitical costs, risks, and benefits;

	ii. The reliability and validity of the evidence used to evaluate the design solutions; and iii. Constraints, including cost, safety, reliability, aesthetics, cultural effects environmental effects. 7. Reasoning/synthesis a. Students use logical arguments based on their evaluation of the design solutions, costs and benefits, empirical evidence, and scientific ideas to support one design over the other(s) in their evaluation. b. Students describe 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 costs and risks.

Crosscutting Concepts

Cause and Effect (HS-ESS3-1)

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to Engineering, Technology, and Applications of Science (HS-ESS3-2)

- 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.

Connections to Nature of Science

- Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.
- Science knowledge indicates what can happen in natural systems — not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.
- Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

Science and Engineering Practices

- **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.
  - Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own

investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. **(HS-ESS3-1)**

- **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 competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). **(HS-ESS3-2)**

Grade Band Endpoints for ESS3-A and ESS3-B

By the end of grade 12

ESS3-A: Resource availability has guided the development of human society and use of natural resources has associated costs, risks, and benefits.

ESS3-B: Natural hazards and other geological events have shaped the course of human history at local, regional, and global scales.

K-12 Endpoint Progression

Suggested Projects

- Community Resilience- Students will explore ideas related to data and how communities can respond to the effects of climate change. They will use their critical thinking skills to address the big question: how can a community become more resilient to the effects of climate change?
- Will there be enough freshwater?- Students explore how water moves above and below Earth's surface by using interactive computational models. Students use NOAA data through a series of interactive modules to answer questions.
- Comparing energy resources: pros and cons- Students form small groups which are each assigned a particular energy resource (e.g., a coal group, a petroleum group, etc.). They will then conduct short research about the pros and cons of their particular energy resource and make an informative poster.
- NGSS@NSTA - project ideas and classroom resources

Modifications to Content/Differentiation	
Priority	Enrichment
-To include suggestions regarding depth of coverage *-Minimum depth of coverage* -Benefits and costs of various resource exploitation and application taught by teacher -overview of natural hazards effect	*-To include suggested extensions to investigations* *-Increased depth* -Benefits and costs of various resource exploitation and application researched by students followed by class discussion -examine the process of natural hazards effect and ways to predict their coming

Suggested Assessments
• Traditional assessment: multiple choice and free response questions, or • The above project(s) using the eight science and engineering practice standards, or • A combination of traditional assessment with project, or • Other format of teacher's choice

ESS3-C: HUMAN IMPACTS ON EARTH SYSTEMS (HS-ESS3-3 and HS-ESS3-4) Compelling Question: *How do humans change the planet?*
Suggested Content– Vocabulary in bold

• Human activities in agriculture, industry, and everyday life have had major impacts on the land, rivers, ocean, and air
  ○ Water: Humans affect the quality, availability, and distribution of Earth's water through the modification of streams, lakes, and groundwater.
  ○ Land: Large areas of land, including such delicate ecosystems as **wetlands**, forests, and **grasslands**, are being transformed by human

agriculture, mining, and the expansion of settlements and roads. Human activities now cause land erosion and soil movement annually that exceed all natural processes.

  - Air: Air and water pollution caused by human activities affect the condition of the atmosphere and of rivers and lakes, with damaging effects on other species and on human health.
  - **Biosphere**: The activities of humans have significantly altered the biosphere, changing or destroying natural **habitats** and causing the **extinction** of many living species.
- These above changes also affect the viability to support human populations.
  - Land use patterns for agriculture and ocean use patterns for fishing are affected not only by changes in population and needs but also by changes in **climate** or local conditions (such as **desertification** due to overuse or **depletion** of fish populations by over-extraction).
- Humans have become one of the most significant agents of change in the **near-surface Earth system**.
- Changes in one system can produce unforeseen changes in others, because all of Earth's subsystems are interconnected.
- The activities and advanced technologies that have built and maintained human civilizations clearly have large consequences for the **sustainability** of these civilizations and the ecosystems with which they interact.
- As the human population grows and **per-capita** consumption of natural resources increases to provide a greater percentage of people with more developed lifestyles and greater **longevity**, so do the human impacts on the planet.
- Some negative effects of human activities are **reversible** with informed and responsible management.
  - Communities and individuals: Treating **sewage**, reducing the amount of materials they use, and reusing and recycling materials.
  - Governments: Establishing regulations regarding water and air pollution have greatly reduced acid rain and stream pollution
  - **International treaties**: Using of certain refrigerant gases have halted the growth of the annual ozone hole over Antarctica. Regulation of fishing and the development of marine preserves can help restore and maintain fish populations.
  - Researches and policies: Development of **alternative energy sources** can reduce the environmental impacts otherwise caused by the use of fossil fuels.
- The sustainability of human societies and of the **biodiversity** that supports them requires
  - Responsible management of natural resources not only to reduce existing adverse impacts but also to prevent such impacts to the

extent possible, and

- Scientists and engineers to make major contributions by developing technologies that produce less **pollution** and waste and that preclude **ecosystem degradation**.

Disciplinary Core Ideas	Observable features of student performance
• The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3) • Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) • 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. *(secondary to HS-ESS3-2),(secondary HS-*	HS-ESS3-3 1. Representation a. Students create a computational simulation (using a spreadsheet or a provided multi-parameter program) that contains representations of the relevant components, including: i. A natural resource in a given ecosystem; ii. The sustainability of human populations in a given ecosystem; iii. Biodiversity in a given ecosystem; and iv. The effect of a technology on a given ecosystem 2. Computational modeling a. Students describe simplified realistic (corresponding to real-world data) relationships between simulation variables to indicate an understanding of the factors (e.g., costs, availability of technologies) that affect the management of natural resources, human sustainability, and biodiversity. (For example, 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 create a simulation using a spreadsheet or provided multi-parameter program that models each component and its simplified mathematical relationship to other components. Examples could include: i. S=C*B*R*T, where S is sustainability of human populations, C is a constant, B is biodiversity, R is the natural resource, and T is a technology used to extract the resource so that if there is zero natural resource, zero technology to extract the resource, or zero biodiversity, the sustainability of human populations is also zero; and ii. B=B1+C*T, where B is biodiversity, B1 is a constant baseline biodiversity, C is a constant that

ESS3-4) (**ETS1.B**: Developing Possible Solutions)	expresses the effect of technology, and T is a given technology, so that a given technology could either increase or decrease biodiversity depending on the value chosen for C. c. The simulation contains user-controlled variables that can illustrate relationships among the components (e.g., technology having either a positive or negative effect on biodiversity). 3. Analysis a. Students use the results of the simulation to: i. Illustrate the effect on one component by altering other components in the system or the relationships between components; ii. Identify the effects of technology on the interactions between human populations, natural resources, and biodiversity; and iii. Identify feedbacks between the components and whether or not the feedback stabilizes or destabilizes the system. b. Students compare the simulation results to a real world example(s) and determine if the simulation can be viewed as realistic. c. Students identify the simulation's limitations relative to the phenomenon at hand. HS-ESS3-4 4. Using scientific knowledge to generate the design solution a. Students use scientific information to generate a number of possible refinements to a given technological solution. Students: i. Describe the system being impacted and how the human activity is affecting that system; ii. Identify the scientific knowledge and reasoning on which the solution is based; iii. Describe how the technological solution functions and may be stabilizing or destabilizing the natural system; iv. Refine a given technological solution that reduces human impacts on natural systems; and v. Describe that the solution being refined comes from scientists and engineers in the real world who develop technologies to solve problems of environmental degradation. 5. Describing criteria and constraints, including quantification when appropriate a. Students describe and quantify (when appropriate): i. Criteria and constraints for the solution to the problem; and

	ii. The tradeoffs in the solution, considering priorities and other kinds of research-driven tradeoffs in explaining why this particular solution is or is not needed. 6. Evaluating potential refinements a. In their evaluation, 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. Their effects on the overall stability of and changes in natural systems; and ii. Cost, safety, aesthetics, and reliability, as well as cultural and environmental impacts.

Crosscutting Concepts

Stability and Change (HS-ESS3-3)

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Stability and Change (HS-ESS3-4)

- Feedback (negative or positive) can stabilize or destabilize a system.

Connections to Engineering, Technology, and Applications of Science

- Influence of Science, Engineering, and Technology on Society and the Natural World (HS-ESS3-3 and 4)
  - Modern civilization depends on major technological systems.
  - New technologies can have deep impacts on society and the environment, including some that were not anticipated.
  - Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Connections to Nature of Science

- Science is a Human Endeavor (HS-ESS3-3)
  - Science is a result of human endeavors, imagination, and creativity.

Science and Engineering Practices

• **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.
  ○ Create a computational model or simulation of a phenomenon, designed device, process, or system. **(HS-ESS3-3)**
 	
• **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 tradeoff considerations. **(HS-ESS3-4)**

Grade Band Endpoint for ESS3-C
By the end of grade 12 Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources, including the development of technologies. K-12 Endpoint Progression
Suggested Projects
• Land and People Finding a Balance- Students investigate human impacts and develop solutions to environmental problems for three different areas: Cape Cod, Everglades, and Los Angeles. • Bioenergy Farm Game- In this board game, players take on the role of bioenergy crop farmers trying to earn a living while being good environmental stewards. In the process, players explore the economic and environmental tradeoffs. • NGSS@NSTA - project ideas and classroom resources

Modifications to Content/Differentiation	
Priority	Enrichment
-To include suggestions regarding depth of coverage *-Minimum depth of coverage* -Systems (such as water, land, air) viewed separately -General view of human impact on the near-surface Earth system	*-To include suggested extensions to investigations* *- Increased depth* -Systems (such as water, land, air) viewed as a combined system for their loop feedback -View in depth, including data, of human impact on the near-surface Earth system

Suggested Assessments
• Traditional assessment: multiple choice and free response questions, or • The above project(s) using the eight science and engineering practice standards, or • A combination of traditional assessment with project, or • Other format of teacher's choice
ESS3-D: GLOBAL CLIMATE CHANGE (HS-ESS3-5 and HS-ESS3-6) Compelling Question: *How do people model and predict the effects of human activities on Earth's climate?*
Suggested Content– Vocabulary in bold

• Driving force of **global climate changes**
  ○ Natural phenomena
  ○ Human activities
  ○ It is clear that human activities play a major role in climate change

- Climate change research and prediction
  - By using science-based predictive **models**, humans can anticipate long-term change more effectively than ever before and plan accordingly.
  - Global changes usually happen too slowly for individuals to recognize, but accumulated human knowledge, together with further scientific research, can help people learn more about these challenges and guide their responses.
  - We can collect historical records of weather conditions and of the times when plants bloom, animals give birth or migrate, and lakes and rivers freeze and thaw
  - Scientists can deduce long-past climate conditions from such sources as fossils, pollen grains found in sediments, and isotope ratios in samples of ancient materials.
- Climate models
  - Scientists build mathematical climate models that simulate the underlying physics and chemistry of the many Earth systems and their complex interactions with each other.
  - These computational models summarize the existing evidence, are tested for their ability to match past patterns, and are then used (together with other kinds of computer models) to forecast how the future may be affected by human activities.
  - Climate models are important tools for predicting
    - When and where new water supplies will be needed,
    - When and which natural resources will become scarce,
    - How weather patterns may change and with what consequences,
    - Whether proposed technological concepts for controlling **greenhouse gases** will work, and
    - How soon people will have to leave low-lying coastal areas if sea levels continue to rise.
- The interactions of climate change
  - Impacts are uneven and may affect some regions, species, or human populations more severely than others.
  - Important discoveries are being made—for example, about how the biosphere is responding to the climate changes that have already occurred, how the atmosphere is responding to changes in **anthropogenic greenhouse gas emissions**, and how greenhouse gases move between the ocean and the atmosphere over long periods.

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- It is clear not only that human activities play a major role in climate change but also that impacts of climate change—for example, increased frequency of severe storms due to ocean warming—have begun to influence human activities.

- Predictions, particularly long-term predictions, always have uncertainties
  - So many complex phenomena
  - Uncertainties in the underlying science
  - Uncertainties about behavioral, economic, and political factors that affect human activity and changes in activity in response to recognition of the problem.
</td></tr>
<tr><th>Disciplinary Core Ideas</th><th>Observable features of student performance</th></tr>
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- 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. (HS-ESS3-5)
- 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
</td><td>

HS-ESS3-5
1. Organizing data
a. Students organize data (e.g., with graphs) from global climate models (e.g., computational simulations) and climate observations over time that relate to the effect of climate change on the physical parameters or chemical composition of the atmosphere, geosphere, hydrosphere, or cryosphere.
b. Students describe what each data set represents.

2. Identifying relationships
a. Students analyze the data and identify and describe relationships within the datasets, including:
i. Changes over time on multiple scales; and
ii. Relationships between quantities in the given data.

3. Interpreting data
a. Students use their analysis of the data to describe a selected aspect of present or past climate and the associated physical parameters (e.g., temperature, precipitation, sea level) or chemical composition (e.g., ocean pH) of the atmosphere, geosphere, hydrosphere or cryosphere.
b. Students use their analysis of the data to predict the future effect of a selected aspect of climate change on the physical parameters (e.g., temperature, precipitation, sea level) or chemical composition (e.g., ocean pH) of the atmosphere, geosphere, hydrosphere or cryosphere.
c. Students describe whether the predicted effect on the system is reversible or irreversible.
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by the ways in which these gases are absorbed by the ocean and biosphere. (secondary) (ESS2.D: Weather and Climate) (HS-ESS3-6) • 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. (HS-ESS3-6)	d. Students identify one source of uncertainty in the prediction of the effect in the future of a selected aspect of climate change. e. In their interpretation of the data, students: i. Make a statement regarding how variation or uncertainty in the data (e.g., limitations, accuracy, any bias in the data resulting from choice of sample, scale, instrumentation, etc.) may affect the interpretation of the data; and ii. Identify the limitations of the models that provided the simulation data and ranges for their predictions. HS-ESS3-6 4. Representation a. Students identify and describe the relevant components of each of the Earth systems modeled in the given computational representation, including system boundaries, initial conditions, inputs and outputs, and relationships that determine the interaction (e.g., the relationship between atmospheric CO_2 and production of photosynthetic biomass and ocean acidification). 5. Computational modeling a. Students use the given computational representation of Earth systems to illustrate 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. 6. Analysis a. Students use evidence from the computational representation to describe how human activity could affect the relationships between the Earth's systems under consideration.

Crosscutting Concepts

Stability and Change (HS-ESS3-5) (same as HS-ESS3-3)

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Systems and System Models (HS-ESS3-6)

- 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.

Connections to Engineering, Technology, and Applications of Science

None

Connections to Nature of Science

None

Science and Engineering Practices

- **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. **(HS-ESS3-5)**
  - Connections to Nature of Science
    - Scientific Investigations Use a Variety of Methods
      - Science investigations use diverse methods and do not always use the same set of procedures to obtain data.
      - New technologies advance scientific knowledge.
    - Scientific Knowledge is Based on Empirical Evidence
      - Science knowledge is based on empirical evidence.
      - Science arguments are strengthened by multiple lines of evidence supporting a single explanation.
- **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. **(HS-ESS3-6)**

Grade Band Endpoint for ESS3-D

By the end of grade 12

Global climate models used to predict changes continue to be improved, although discoveries about the global climate system are ongoing and continually needed.

K-12 Endpoint Progression

Suggested Projects

- UN Climate Council- Students act as members of the UN Climate Council and working within teams, identify and address the major factors of climate change. Students are instructed to identify three major factors of climate change through research.
- Climate Science in Focus- Students explore topics including climate and weather, carrying capacity and animal adaptations, watershed and human influences on them, climate science data exploring streamflow, and have a virtual tour of a National Park Service site.
- The Ocean-Carbon Connection- The Ocean-Carbon Connection is a step in understanding ocean acidification; students examine graphs and maps to identify changes in pH, sea surface temperatures (SST), and dissolved CO2 levels in the Caribbean. Students then correlate changes in pH and SST to changes in CO2 levels over time.
- NGSS@NSTA - project ideas and classroom resources

Modifications to Content/Differentiation

Priority	Enrichment
-To include suggestions regarding depth of coverage *-Minimum depth of coverage* -General view of global climate changes, causes and impacts -Understand the functions of climate models	*-To include suggested extensions to investigations* *-Increased depth* -Description of global climate changes, causes, impacts and positive and negative feedback loops of the systems -Understand the functions of climate models and how they work

Suggested Assessments

- Traditional assessment: multiple choice and free response questions, or
- The above project(s) using the eight science and engineering practice standards, or
- A combination of traditional assessment with project, or
- Other format of teacher's choice

Pacing Guide

- Suggested/tentative timeline
- Class periods (80 min/block instructional time)
- Class is taught over a 45 day Semester

Suggested span of instructional time	Content
6 class periods	ESS1. Earth's Place in the Universe
14 class periods	ESS2. Earth's Systems
20 class periods	ESS3. Earth and Human Activity

Pacing Guide

- Suggested/tentative timeline
- Class periods (80 min/block instructional time)
- Class is taught over a 45 day Semester

Suggested sequence over 45 days	Activity	Content
1-2	-Establish guide lines of course -Establish talk move guidelines for discussion -Establish modeling practices	
		Earth's Place in the Universe
3-4	-Develop models of life cycle of stars - Fusion - Extent of matter and energy in Universe	ESS1-A
5-6	-Develop models that demonstrate cyclic patterns of orbital movement with seasons. - Proper use of gravitational influence by objects on tides,	ESS1-B
7-8	-Discuss use of fossil record to understand how planet has changed with respect to geology, ecosystems and history of universe	ESS1-C
9-10	Assessment	
		Earth's Systems
11-12	-Model Earth layers	ESS2-A

	-Properly defend movement and forces conducting plate movement. -Discuss relationships of climate change over time with respect to Solar system and planetary forces	
13-15	-Relate composition of inner layers of planet to resulting planetary forces and plate movement. -Evolution of mountains and volcanoes along with persistent magnetic field	ESS2-B
16-18	-Discuss properties of water -water's crucial role in erosion, movement of material and energy on the planet	ESS2-C
19-21	-Distinction between weather and climate -use of data to understand relationship of changing weather patterns from geologic and biological influences -predict and model potential changes based on changes that have occurred over time	ESS2-D
22-25	-Debate and discuss the impact of organisms on climate and the planet both short term and long term.	ESS2-E
26-27	Assessment	
		Earth and Human Activity
28-30	-Discuss dependence of humans on resources and how this has changed; - geology -climate -weather - Biodiversity	ESS3-A
31-33	-Discuss effect of natural disasters on: - access to resources - Climate and biodiversity - Impacts to economy, society	ESS3-B
34-37	-Debate negative impacts of humans on water based on society's needs	ESS3-C
38-43	-Use of data to debate and model potential changes in climates based on trending observations	ESS3-D
44-45	Assessment	