HS-ESS1-1 Earth's Place in the Universe

Science & Engineering Practices

❶ Asking questions (for science) and defining problems (for engineering)
❷ **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 components of a system.**

❸ Planning and carrying out investigations
❹ Analyzing and interpreting data
❺ Using mathematics and computational thinking
❻ Constructing explanations (for science) and designing solutions (for engineering)
❼ Engaging in argument from evidence
❽ Obtaining, evaluating, and communicating information

Disciplinary Core Ideas

The Universe and Its Stars:
- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.

Energy in Chemical Processes and Everyday Life:
(secondary to HS-ESS1-1)
- Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.

Performance Expectations

HS-ESS1-1

Students who demonstrate understanding can:

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 sub-atomic processes involved with the sun's nuclear fusion.

Crosscutting Concepts: Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Oklahoma Academic Standards Connections

ELA/Literacy

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

Mathematics

MP.2 Reason abstractly and quantitatively.
MP.4 Model with mathematics.
HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.
HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
HAS-SSE.A.1 Interpret expressions that represent a quantity in terms of its context.
HAS-CED.A.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
HAS-CED.A.2 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ESS1-2 Earth's Place in the Universe

Science & Engineering Practices	Disciplinary Core Ideas	Performance Expectations
❶ Asking questions (for science) and defining problems (for engineering) ❷ **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 components of a system.** ❸ Planning and carrying out investigations ❹ Analyzing and interpreting data ❺ Using mathematics and computational thinking ❻ Constructing explanations (for science) and designing solutions (for engineering) ❼ Engaging in argument from evidence ❽ Obtaining, evaluating, and communicating information	**Earth and the Solar System:** • The solar system consists of a collection of objects of varying sizes and conditions – including planets and their moons – that are held in orbit around the sun by its gravitational pull on them.	**HS-ESS1-2** *Students who demonstrate understanding can:* **Develop models to describe the sun's place in relation to the Milky Way galaxy and the distribution of galaxies and galaxy clusters in the Universe.** **Clarification Statement:** Mathematical models can focus on the logarithmic powers-of-ten relationship among the sun, its solar system, the Milky Way galaxy, the local cluster of galaxies, and the universe, these relationships can also be investigated graphically, using 2D or 3D scaled models, or through computer programs, either pre-made or student-written. **Assessment Boundary:** Details about the mapped distribution of galaxies and clusters are not assessed.

Crosscutting Concepts: Scale, Proportion, and Quantity

• The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
N/A	**MP.2** Reason abstractly and quantitatively. **MP.4** Model with mathematics.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ESS1-3 Earth's Place in the Universe

Science & Engineering Practices	Disciplinary Core Ideas	Performance Expectations
❶ Asking questions (for science) and defining problems (for engineering) ❷ Developing and using models ❸ Planning and carrying out investigations ❹ Analyzing and interpreting data ❺ Using mathematics and computational thinking ❻ Constructing explanations (for science) and designing solutions (for engineering) ❼ Engaging in argument from evidence ❽ **Obtaining, evaluating, and communicating information Obtaining, evaluating, and communicating information in 9–12 builds on K –8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.** • **Communicate scientific (e.g. about phenomena and/or the process of development and the design and performance of a proposed process of system) in multiple formats (including orally, graphically, textually, and mathematically).**	**The Universe and Its Stars:** • The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. • Other than the hydrogen and helium, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electro-magnetic energy. • Heavier elements are produced when certain massive stars achieve a supernova stage and explode.	**HS-ESS1-3** *Students who demonstrate understanding can:* **Communicate scientific ideas about the way stars, over their life cycle, produce elements.** **Clarification Statement:** Emphasis is on the way nucleo-synthesis, and therefore the different elements created, depend on 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.

Crosscutting Concepts: Energy and Matter

• In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. **SL.11-12.4** Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and w ell-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.	**MP.2** Reason abstractly and quantitatively.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ESS1-4 Earth's Place in the Universe

Science & Engineering Practices

❶ Asking questions (for science) and defining problems (for engineering)
❷ Developing and using models
❸ Planning and carrying out investigations
❹ Analyzing and interpreting data
❺ **Using mathematics and computational thinking**
Mathematical and computational thinking at the 9–12 level builds on K–8 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 representations of phenomena or design solutions to support and revise explanations.**

❻ Constructing explanations (for science) and designing solutions (for engineering)
❼ Engaging in argument from evidence
❽ Obtaining, evaluating, and communicating information

Disciplinary Core Ideas

Earth and the Solar System:
- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

** Connections to Engineering, Technology, and Application of Science*

Interdependence of Science, Engineering, and Technology:
- Science and engineering compliment 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.

Performance Expectations

HS-ESS1-4

Students who demonstrate understanding can:

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. (e.g. graphical representations of orbits)

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.

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).

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
N/A	**MP.2** Reason abstractly and quantitatively. **MP.4** Model with mathematics. **HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. **HAS-SSE.A.1** Interpret expressions that represent a quantity in terms of its context. **HAS-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. **HAS-CED.A.2** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ESS1-5 Earth's Place in the Universe

Science & Engineering Practices	Disciplinary Core Ideas	Performance Expectations
❶ Asking questions (for science) and defining problems (for engineering) ❷ Developing and using models ❸ Planning and carrying out investigations ❹ Analyzing and interpreting data ❺ Using mathematics and computational thinking ❻ Constructing explanations (for science) and designing solutions (for engineering) ❼ **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 worlds. Arguments may also come from current scientific or historical episodes in science.** • **Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.** ❽ Obtaining, evaluating, and communicating information	**Plate Tectonics and Large-Scale System Interactions:** • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history.	**HS-ESS1-5** *Students who demonstrate understanding can:* **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 (a result of past plate interactions). **Assessment Boundary:** N/A

Crosscutting Concepts: Stability and Change

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

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **RST.11-12.8** Evaluate the hypotheses, data, analysis and conclusion in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.	**MP.2** Reason abstractly and quantitatively. **HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ESS1-6 Earth's Place in the Universe

Science & Engineering Practices	Disciplinary Core Ideas	Performance Expectations
❶ Asking questions (for science) and defining problems (for engineering) ❷ Developing and using models ❸ Planning and carrying out investigations ❹ Analyzing and interpreting data ❺ Using mathematics and computational thinking ❻ **Constructing explanations (for science) and designing solutions (for engineering)** **Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student- generated sources of evidence consistent with scientific ideas, principles, and theories.** • **Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.** ❼ Engaging in argument from evidence ❽ Obtaining, evaluating, and communicating information	**History of Planet Earth:** • 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 years. Studying these objects can provide information about Earth's formation and early history.	**HS-ESS1-6** *Students who demonstrate understanding can:* **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. Examples of evidence include materials obtained through space exploration, radiometric dating of meteorites and Earth's oldest minerals, the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.

Crosscutting Concepts: Stability and Change

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

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **RST.11-12.8** Evaluate the hypotheses, data, analysis and conclusion in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **WHST.9-12.1** Write arguments focused on discipline-specific content.	**MP.2** Reason abstractly and quantitatively. **HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. **HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. **HSS-ID.B.6** Represent data on two quantitative variables on a scatter plot, and describe how those variables are related.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ESS2-1 Earth's Systems

Science & Engineering Practices	Disciplinary Core Ideas	Performance Expectations
❶ Asking questions (for science) and defining problems (for engineering) ❷ **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 components of a system.** ❸ Planning and carrying out investigations ❹ Analyzing and interpreting data ❺ Using mathematics and computational thinking ❻ Constructing explanations (for science) and designing solutions (for engineering) ❼ Engaging in argument from evidence ❽ Obtaining, evaluating, and communicating information	**Earth Materials and Systems:** • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. **Plate Tectonics and Large-Scale System Interactions:** • Plate tectonics is the unifying theory that explains the past and current movements of 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.	**HS-ESS2-1** *Students who demonstrate understanding can:* **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, erosion, and mass wasting). **Assessment Boundary:** Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.

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.

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.	**MP.2** Reason abstractly and quantitatively. **MP.4** Model with mathematics. **HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. **HSF-IF.B.6** Calculate and interpret the average rate of change of function (presented symbolically or as a table) over specified interval. Estimate the rate of change from a graph.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ESS2-2 Earth's Systems

Science & Engineering Practices	Disciplinary Core Ideas	Performance Expectations
❶ Asking questions (for science) and defining problems (for engineering) ❷ Developing and using models ❸ Planning and carrying out investigations ❹ **Analyzing and interpreting data** **Analyzing data in 9–12 builds on K–8 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.** ❺ Using mathematics and computational thinking ❻ Constructing explanations (for science) and designing solutions (for engineering) ❼ Engaging in argument from evidence ❽ Obtaining, evaluating, and communicating information	**Earth Materials and Systems:** • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. **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.	**HS-ESS2-2** *Students who demonstrate understanding can:* **Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks and interactions that cause changes to other Earth's systems.** **Clarification Statement:** Examples could be taken from system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion, which limits additional vegetation patterns; how dammed rivers increase ground-water 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. Examples could also include climate feedbacks that increase surface temperatures through geologic time. **Assessment Boundary:** N/A

Crosscutting Concepts: Stability and Change

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

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **RST.11-12.2** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.	**MP.2** Reason abstractly and quantitatively. **HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

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HS-ESS2-3 Earth's Systems

Science & Engineering Practices

❶ Asking questions (for science) and defining problems (for engineering)
❷ **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 components of a system.**

❸ Planning and carrying out investigations
❹ Analyzing and interpreting data
❺ Using mathematics and computational thinking
❻ Constructing explanations (for science) and designing solutions (for engineering)
❼ Engaging in argument from evidence
❽ Obtaining, evaluating, and communicating information

Disciplinary Core Ideas

Earth Materials and Systems:
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface features, 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.

Plate Tectonics and Large-Scale System Interactions:
- The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection.
- Plate tectonics can be viewed as the surface expression of mantle convection.

Waves Properties:
(secondary to HS-ESS2-3)
- Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet.

Performance Expectations

HS-ESS2-3

Students who demonstrate understanding can:

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 the Earth's surface features as well as three-dimensional structure in the subsurface, obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and prediction of the composition of Earth's layers from high-pressure laboratory experiments.

Assessment Boundary:
N/A

Crosscutting Concepts: Energy and Matter

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

Oklahoma Academic Standards Connections

ELA/Literacy

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Mathematics

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

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HS-ESS2-4 Earth's Systems

Science & Engineering Practices

❶ Asking questions (for science) and defining problems (for engineering)
❷ Developing and using models
❸ Planning and carrying out investigations
❹ **Analyzing and interpreting data**
Analyzing data in 9–12 builds on K–8 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.**

❺ Using mathematics and computational thinking
❻ Constructing explanations (for science) and designing solutions (for engineering)
❼ Engaging in argument from evidence
❽ Obtaining, evaluating, and communicating information

Disciplinary Core Ideas

Earth and the Solar System:
(secondary to HS-ESS2-4)
- 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 changes in climate.

Earth Materials and Systems:
- 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.

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.

Performance Expectations

HS-ESS2-4

Students who demonstrate understanding can:

Analyze and interpret data to explore how variations in the flow of energy into and out of Earth's systems result in changes in atmosphere and climate.

Clarification Statement:
Changes differ by timescale, from sudden (large volcanic eruption, ocean circulation); to intermediate (ocean circulation, solar output, human activity) and long-term (Earth's orbit and the orientation of its axis and changes in atmospheric composition). Examples of human activities could include fossil fuel combustion, cement production, or agricultural activity and natural processes such as changes in incoming solar radiation or volcanic activity. Examples of data can include tables, graphs, maps of global and regional temperatures, and atmospheric levels of gases.

Assessment Boundary:
N/A

Crosscutting Concepts: Cause and Effect

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

Oklahoma Academic Standards Connections

ELA/Literacy

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Mathematics

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ESS2-5 Earth's Systems

Science & Engineering Practices

❶ Asking questions (for science) and defining problems (for engineering)
❷ Developing and using models
❸ **Planning and carrying out investigations**
Planning and carrying out investigations in 9-12 builds on 6-8 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.**

❹ Analyzing and interpreting data
❺ Using mathematics and computational thinking
❻ Constructing explanations (for science) and designing solutions (for engineering)
❼ Engaging in argument from evidence
❽ Obtaining, evaluating, and communicating information

Disciplinary Core Ideas

The Role of Water in Earth's Surface Processes:
- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

Performance Expectations

HS-ESS2-5

Students who demonstrate understanding can:

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).

Assessment Boundary:
N/A

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.

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.	**HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ESS2-6 Earth's Systems

Science & Engineering Practices	Disciplinary Core Ideas	Performance Expectations
❶ Asking questions (for science) and defining problems (for engineering) ❷ **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 components of a system.** ❸ Planning and carrying out investigations ❹ Analyzing and interpreting data ❺ Using mathematics and computational thinking ❻ Constructing explanations (for science) and designing solutions (for engineering) ❼ Engaging in argument from evidence ❽ Obtaining, evaluating, and communicating information	**Biogeology:** • Organisms ranging from bacteria to human beings are a major driver of the global carbon and they influence global climate by modifying the chemical makeup of the atmosphere. • The abundance of carbon in the atmosphere is reduced through the ocean floor accumulation of marine sediments and the accumulation of plant biomass.	**HS-ESS2-6** *Students who demonstrate understanding can:* **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:** N/A

Crosscutting Concepts: Energy and Matter

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

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
N/A	**MP.2** Reason abstractly and quantitatively. **MP.4** Model with mathematics. **HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ESS2-7 Earth's Systems

Science & Engineering Practices

❶ Asking questions (for science) and defining problems (for engineering)
❷ Developing and using models
❸ Planning and carrying out investigations
❹ Analyzing and interpreting data
❺ Using mathematics and computational thinking
❻ Constructing explanations (for science) and designing solutions (for engineering)
❼ **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 worlds. 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.**

❽ Obtaining, evaluating, and communicating information

Disciplinary Core Ideas

Weather and Climate:
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.

Biogeology:
- The many dynamic and delicate feedback mechanisms between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.

Performance Expectations

HS-ESS2-7

Students who demonstrate understanding can:

Construct an argument based on evidence about the simultaneous co-evolution 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 influence conditions for life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and affected animal life; how microbial life on land increased the formation of soil, which in turn allowed for the development of land plant species; or how the changes in coral species created reefs that altered patterns of erosion and deposition along coastlines and provided habitats to support biodiversity. Geologic timescale should be considered with the emphases above.

Assessment Boundary:
Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of 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.

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
WHST.9-12.1 Write arguments focused on discipline-specific content.	**N/A**

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HS-ESS3-1 Earth and Human Activities

Science & Engineering Practices	Disciplinary Core Ideas	Performance Expectations
❶ Asking questions (for science) and defining problems (for engineering) ❷ Developing and using models ❸ planning and carrying out investigations ❹ Analyzing and interpreting data ❺ Using mathematics and computational thinking ❻ **Constructing explanations (for science) and designing solutions (for engineering)** **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, 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.** ❼ Engaging in argument from evidence ❽ Obtaining, evaluating, and communicating information	**Natural Resources:** • Resource availability has guided the development of human society. **Natural Hazards:** • 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** *Students who demonstrate understanding can:* **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). Natural hazards and other geologic events exhibit some non-random patterns of occurrence. 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. **Assessment Boundary:** N/A

Crosscutting Concepts: Cause and Effect

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

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.	**MP.2** Reason abstractly and quantitatively. **HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

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HS-ESS3-2 Earth and Human Activities

Science & Engineering Practices

❶ Asking questions (for science) and defining problems (for engineering)
❷ Developing and using models
❸ Planning and carrying out investigations
❹ Analyzing and interpreting data
❺ Using mathematics and computational thinking
❻ Constructing explanations (for science) and designing solutions (for engineering)
❼ **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 worlds. 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).**

❽ Obtaining, evaluating, and communicating information

Disciplinary Core Ideas

Natural Resources:
- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

Developing Possible Solutions:
(secondary to HS-ESS3-2)
- 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.

Performance Expectations

HS-ESS3-2

Students who demonstrate understanding can:

Evaluate competing design solutions for developing, managing, and utilizing natural 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, forestry, and mining.

Assessment Boundary:
N/A

Crosscutting Concepts: Cause and Effect
- N/A

Oklahoma Academic Standards Connections

ELA/Literacy

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Mathematics

MP.2 Reason abstractly and quantitatively.

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HS-ESS3-5 Earth and Human Activities

Science & Engineering Practices	Disciplinary Core Ideas	Performance Expectations
❶ Asking questions (for science) and defining problems (for engineering) ❷ Developing and using models ❸ Planning and carrying out investigations ❹ Analyzing and interpreting data ❺ Using mathematics and computational thinking ❻ **Constructing explanations (for science) and designing solutions (for engineering)** **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, 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.** ❼ Engaging in argument from evidence ❽ Obtaining, evaluating, and communicating information	**Natural Resources:** • Most elements exist in Earth's crust at concentrations too low to be extracted, but in some locations-where geological processes have concentrated them- extraction is economically viable.	**HS-ESS3-5** *Students who demonstrate understanding can:* **Construct a scientific explanation from evidence for how geological processes lead to uneven distribution of natural resources.** **Clarification Statement:** Emphasis is on how geological processes have led to geological sedimentary basins that provide significant accumulations of crude oil and natural gas in some areas and not others and how geological processes lead to diverse soil profiles that support a diversity and range of agricultural crops and how plate-tectonics leads to concentrations of mineral deposits. **Assessment Boundary:** N/A

Crosscutting Concepts: Cause and Effect

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

Oklahoma Academic Standards Connections

ELA/Literacy	Mathematics
RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. **WHST.9-12.9** Draw evidence from informational texts to support analysis, reflection, and research. conclusions with other sources of information.	**N/A**

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