

## Louisiana Student Standards for Science

The Louisiana Student Standards for Science were created by over eighty content experts and educators with input from parents and teachers from across the state. Educators envisioned what students should know and be able to do to compete in our communities and created standards that would allow students to do so. The Louisiana Student Standards for Science provide appropriate content for all grades or courses, maintain high expectations and create a logical connection of content across and within grades.

The Louisiana Student Standards for Science represent the knowledge and skills needed for students to successfully transition to postsecondary educations and the workplace. The standards call for students to:

- Apply content knowledge to real world phenomena and to design solutions
- Demonstrate the practices of scientists and engineers
- Connect scientific learning to all disciplines of science
- Express ideas grounded in scientific evidence

The Louisiana Student Standards do not dictate curriculum or teaching methods. Decisions about how to teach these expectations are left to local districts, schools, and teachers.

## Structure and Components of the Standards

The Louisiana Student Standards for Science are arranged by grade levels for kindergarten through grade 8 and content areas for high school. The standards include:

- **Performance expectations** define what students should be able to do by the end of the year.
- **Science and engineering practices** are the practices that scientists and engineers use when investigating real world phenomena and designing solutions to problems. There are eight science and engineering practices that apply to all grade levels and content areas.
  1. Asking questions (science) and defining problems (engineering)
  2. Developing and using models
  3. Planning and carrying out investigations
  4. Analyzing and interpreting data
  5. Using mathematical and computational thinking
  6. Constructing explanations (science) and designing solutions (engineering)
  7. Engaging in argument with evidence
  8. Obtaining, evaluating, and communicating information
- **Disciplinary Core Ideas** describe the most essential ideas (content) in the major science disciplines that students will learn. Disciplinary Core Ideas are grouped into five science domains.
  1. Physical Science (PS)
  2. Life Science (LS)
  3. Earth and Space Science (ESS)
  4. Environmental Science (EVS)
  5. Engineering, Technology, and Applications of Science (ETS)
- **Crosscutting Concepts** are common themes that have application across all disciplines of science and allow students to connect learning within and across grade levels or content areas. The seven crosscutting concepts apply to all grade levels and content areas.
  1. Patterns
  2. Cause and effect
  3. Scale, proportion, and quantity
  4. Systems and models
  5. Energy and matter
  6. Structure and function
  7. Stability and change
- **Clarification statements** provide examples or additional explanation to the performance expectation.

### Interpreting Standard Codes

Each performance expectation is identified by a code and descriptor. The coding is derived by the following formula: Grade level-Domain and Topic Number- Performance Expectation Number (space)

3-PS2-1 Motion and Stability: Forces and Interactions	The grade level is 3, the domain is Physical Science, the topic number is 2, and the performance expectation number is 1. The descriptor is, "Motion and Stability: Forces and Interactions."
7-MS-ESS2-4 Earth's Systems	The grade level is 7, the standard is middle school, the domain is Earth and Space Science, the topic number is 2, and the performance expectation is 1. The descriptor is, "Earth's Systems."
HS-LS1-1 From Molecules to Organisms: Structures and Processes	The standard is high school, the domain is Life Science, the topic number is 1, and the performance expectation number is 1. The descriptor is, "From Molecules to Organisms: Structures and Processes."

**8-MS-PS1-1**

**Grade Level:** 8  
**Standard:** MS  
**Domain:** PS  
**Performance Expectation:** 1  
**Topic Number:** 1

**Descriptor:** MATTER AND ITS INTERACTIONS

<b>Performance Expectation</b>		Develop models to describe the atomic composition of simple molecules and extended structures.
<b>Clarification Statement</b>		Emphasis is on developing models of molecules that vary in complexity. Examples of extended structures could include minerals such as but not limited to halite (NaCl), agate (SiO <sub>2</sub> ), calcite (CaF <sub>2</sub> ), or sapphire (Al <sub>2</sub> O <sub>3</sub> ). Examples of molecular-level models could include drawings, 3-D models, or computer representations showing different molecules with different types of atoms.
<b>Science &amp; Engineering Practices</b>	<b>Disciplinary Core Ideas</b>	<b>Crosscutting Concepts</b>
<ol style="list-style-type: none"> <li>Asking questions (for science) and defining problems (for engineering)</li> <li><b>Developing and using models:</b> Modeling in 6–8 builds on K–5 experiences and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems. <ul style="list-style-type: none"> <li>Develop and/or use a model to predict and/or describe phenomena.</li> </ul> </li> <li>Planning and carrying out investigations</li> <li>Analyzing and interpreting data</li> <li>Using mathematics and computational thinking</li> <li>Constructing explanations and designing solutions</li> <li>Engaging in argument from evidence</li> <li>Obtaining, evaluating, and communicating information</li> </ol>	<p><b>STRUCTURE AND PROPERTIES OF MATTER</b> Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS.PS1A.a)</p> <p>Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS.PS1A.e)</p>	<p><b>SCALE, PROPORTION, AND QUANTITY</b> Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.</p>

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## EARTH'S PLACE IN THE UNIVERSE

<p><b>Performance Expectation</b></p>	<p>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.</p>
<p><b>Clarification Statement</b></p>	<p>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.</p>

<p><b>Science &amp; Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>	<p><b>Crosscutting Concepts</b></p>
<ol style="list-style-type: none"> <li>Asking questions and defining problems</li> <li><b>Developing and using models:</b> 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 worlds. <ul style="list-style-type: none"> <li>Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.</li> </ul> </li> <li>Planning and carrying out investigations</li> <li>Analyzing and interpreting data</li> <li>Using mathematics and computational thinking</li> <li>Constructing explanations and designing solutions</li> <li>Engaging in argument from evidence</li> <li>Obtaining, evaluating, and communicating information</li> </ol>	<p><b>THE UNIVERSE AND ITS STARS</b> All stars, such as our sun, are evolving. The star called Sol, our sun, will burn out over a lifespan of approximately 10 billion years. (HS.ESS1A.a)</p> <p>The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS.ESS1A.c)</p> <p><b>ENERGY IN CHEMICAL PROCESSES AND EVERYDAY LIFE</b> Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (HS.PS3D.c)</p>	<p><b>SCALE, PROPORTION, AND QUANTITY</b> The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.</p>

## EARTH'S SYSTEMS

<b>Performance Expectation</b>	Plan and conduct an investigation on the properties of water and its effects on Earth materials and surface processes.
<b>Clarification Statement</b>	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)

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. Developing and using models</li> <li>3. <b>Planning and carrying out investigations:</b> Planning and carrying out investigations to answer questions (science) or test solutions (engineering) to problems 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. <ul style="list-style-type: none"> <li>• Plan an investigation (science) or test a design (engineering) individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.</li> </ul> </li> <li>4. Analyzing and interpreting data</li> <li>5. Using mathematics and computational thinking</li> <li>6. Constructing explanations and designing solutions</li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>THE ROLE OF WATER IN EARTH'S SURFACE PROCESSES</b></p> <p>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 (HS.ESS2C.a)</p>	<p><b>STRUCTURE AND FUNCTION</b></p> <p>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.</p>

## SPACE SYSTEMS

<b>Performance Expectation</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.
<b>Clarification Statement</b>	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 intersellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by Big Bang theory.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. Developing and using models</li> <li>3. Planning and carrying out investigations</li> <li>4. Analyzing and interpreting data</li> <li>5. Using mathematics and computational thinking</li> <li>6. <b>Constructing explanations and designing solutions:</b> Constructing explanations (science) and designing solutions (engineering) 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.               <ul style="list-style-type: none"> <li>• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</li> </ul> </li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>THE UNIVERSE AND ITS STARS</b></p> <p>The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS.ESS1A.b)</p> <p>The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS.ESS1A.c)</p> <p>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.ESS1A.d)</p> <p><b>ELECTROMAGNETIC RADIATION</b></p> <p>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. (HS.PS4B.d)</p>	<p><b>ENERGY AND MATTER</b></p> <p>Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.</p>

## EARTH'S PLACE IN THE UNIVERSE

<b>Performance Expectation</b>	Communicate scientific ideas about the way stars, over their life cycle, produce elements.
<b>Clarification Statement</b>	Emphasis is on the way nucleosynthesis, and therefore the different elements created, depends on the mass of a star and the stage of its lifetime.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. Developing and using models</li> <li>3. Planning and carrying out investigations</li> <li>4. Analyzing and interpreting data</li> <li>5. Using mathematics and computational thinking</li> <li>6. Constructing explanations and designing solutions</li> <li>7. Engaging in argument from evidence</li> <li>8. <b>Obtaining, evaluating, and communicating information:</b> 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. <ul style="list-style-type: none"> <li>• Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).</li> </ul> </li> </ol>	<p><b>THE UNIVERSE AND ITS STARS</b> The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS.ESS1A.b)</p> <p>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.ESS1A.d)</p> <p><b>ENERGY IN CHEMICAL PROCESSES AND EVERYDAY LIFE</b> Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (HS.PS3D.c)</p>	<p><b>ENERGY AND MATTER</b> In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.</p>

## EARTH'S PLACE IN THE UNIVERSE

<b>Performance Expectation</b>	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.
<b>Clarification Statement</b>	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 continental center (a result of past plate interactions).



<b>Science &amp; Engineering Practices</b>	<b>Disciplinary Core Ideas</b>	<b>Crosscutting Concepts</b>
<ol style="list-style-type: none"> <li>Asking questions and defining problems</li> <li>Developing and using models</li> <li>Planning and carrying out investigations</li> <li>Analyzing and interpreting data</li> <li>Using mathematics and computational thinking</li> <li>Constructing explanations and designing solutions</li> <li><b>Engaging in argument from evidence:</b> 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. <ul style="list-style-type: none"> <li>Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.</li> </ul> </li> <li>Obtaining, evaluating, and communicating information</li> </ol>	<p><b>THE HISTORY OF PLANET EARTH</b> 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.ESS1C.b)</p> <p>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.ESS1C.c)</p> <p><b>PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS</b> 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.ESS2B.a)</p> <p><b>NUCLEAR PROCESSES</b> 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. (HS.PS1C.b)</p>	<p><b>PATTERNS</b> Empirical evidence is needed to identify patterns.</p>

## HISTORY OF EARTH

<p><b>Performance Expectation</b></p>	<p>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.</p>
<p><b>Clarification Statement</b></p>	<p>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 include the absolute age of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth’s oldest materials), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.</p>

<p><b>Science &amp; Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>	<p><b>Crosscutting Concepts</b></p>
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. Developing and using models</li> <li>3. Planning and carrying out investigations</li> <li>4. Analyzing and interpreting data</li> <li>5. Using mathematics and computational thinking</li> <li>6. <b>Constructing explanations and designing solutions:</b> Constructing explanations (science) and designing solutions (engineering) 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. <ul style="list-style-type: none"> <li>• Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.</li> </ul> </li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>THE HISTORY OF PLANET EARTH</b> 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.ESS1C.c)</p> <p><b>NUCLEAR PROCESSES</b> 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. (HS.PS1C.b)</p>	<p><b>STABILITY AND CHANGE</b> Much of science deals with constructing explanations of how things change and how they remain stable.</p>

## EARTH'S PLACE IN THE UNIVERSE

<b>Performance Expectation</b>	Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.
<b>Clarification Statement</b>	Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as other celestial bodies (e.g. graphical representations of orbits).



Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. Developing and using models</li> <li>3. Planning and carrying out investigations</li> <li>4. Analyzing and interpreting data</li> <li>5. <b>Using mathematics and computational thinking:</b> 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 (e.g. trigonometric, exponential and logarithmic) 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.</li> <li>• Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.</li> <li>6. Constructing explanations and designing solutions</li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>EARTH AND THE SOLAR SYSTEM</b> 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. (HS.ESS1B.a)</p>	<p><b>SCALE, PROPORTIONS AND QUANTITY</b> 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).</p>

## EARTH'S SYSTEMS

<p><b>Performance Expectation</b></p>	<p>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.</p>
<p><b>Clarification Statement</b></p>	<p>Emphasis is on the processes by which rocks and minerals are formed and 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).</p>

<p><b>Science &amp; Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>	<p><b>Crosscutting Concepts</b></p>
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. <b>Developing and using models:</b> 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 worlds. <ul style="list-style-type: none"> <li>• Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.</li> </ul> </li> <li>3. Planning and carrying out investigations</li> <li>4. Analyzing and interpreting data</li> <li>5. Using mathematics and computational thinking</li> <li>6. Constructing explanations and designing solutions</li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>EARTH MATERIALS AND SYSTEMS</b> Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS.ESS2A.a)</p> <p><b>PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS</b> 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. (HS.ESS2B.a)</p> <p>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.ESS2B.b)</p>	<p><b>STABILITY AND CHANGE</b> Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</p>

## EARTH'S SYSTEMS

<p><b>Performance Expectation</b></p>	<p>Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems.</p>
<p><b>Clarification Statement</b></p>	<p>Examples could 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 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.</p>

<p><b>Science &amp; Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>	<p><b>Crosscutting Concepts</b></p>
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. Developing and using models</li> <li>3. Planning and carrying out investigations</li> <li>4. <b>Analyzing and interpreting data:</b> 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 <ul style="list-style-type: none"> <li>• 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.</li> </ul> </li> <li>5. Using mathematics and computational thinking</li> <li>6. Constructing explanations and designing solutions</li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>EARTH MATERIALS AND SYSTEMS</b> Earth's systems, being dynamic and interacting, include feedback effects that can increase or decrease the original changes. (HS.ESS2A.a)</p> <p><b>WEATHER AND CLIMATE</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, hydrosphere, and land systems, and this energy's re-radiation into space. (HS.ESS2D.a)</p>	<p><b>STABILITY AND CHANGE</b> Feedback (negative or positive) can stabilize or destabilize a system.</p>

## EARTH'S SYSTEMS

<b>Performance Expectation</b>	Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.
<b>Clarification Statement</b>	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 three-dimensional structure obtained from seismic wave data, 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.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. <b>Developing and using models:</b> 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 worlds.               <ul style="list-style-type: none"> <li>• Develop a model based on evidence to illustrate the relationships between systems or components of a system.</li> </ul> </li> <li>3. Planning and carrying out investigations</li> <li>4. Analyzing and interpreting data</li> <li>5. Using mathematics and computational thinking</li> <li>6. Constructing explanations and designing solutions</li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>EARTH MATERIALS AND SYSTEMS</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 viscous mantle and solid crust. (HS.ESS2A.b)</p> <p>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.ESS2A.c)</p> <p><b>PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS</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 convection. Plate tectonics can be viewed as the surface expression of mantle convection. (HS.ESS2B.c)</p> <p><b>WAVE PROPERTIES</b> Geologists use seismic waves and their reflections at interfaces between layers to probe structures deep in the planet. (HS.PS4A.c)</p>	<p><b>ENERGY AND MATTER</b> Energy drives the cycling of matter within and between systems.</p>

## EARTH'S SYSTEMS

<b>Performance Expectation</b>	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.
<b>Clarification Statement</b>	Changes differ by timescale, from sudden (large volcanic eruption, hydrosphere circulation) to intermediate (hydrosphere 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.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<ol style="list-style-type: none"> <li>Asking questions and defining problems</li> <li>Developing and using models</li> <li>Planning and carrying out investigations</li> <li><b>Analyzing and interpreting data:</b> 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 <ul style="list-style-type: none"> <li>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</li> </ul> </li> <li>Using mathematics and computational thinking</li> <li>Constructing explanations and designing solutions</li> <li>Engaging in argument from evidence</li> <li>Obtaining, evaluating, and communicating information</li> </ol>	<p><b>EARTH AND THE SOLAR SYSTEM</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 Earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (HS.ESS1B.b)</p> <p><b>EARTH MATERIALS AND SYSTEMS</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, hydrosphere 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.ESS2A.d)</p> <p><b>WEATHER AND CLIMATE</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, hydrosphere and land systems, and this energy's re-radiation into space. (HS.ESS2D.a)</p> <p>Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS.ESS2D.b)</p> <p>Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS.ESS2D.c)</p>	<p><b>CAUSE AND EFFECT</b> Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</p>

## EARTH'S SYSTEMS

<b>Performance Expectation</b>	Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
<b>Clarification Statement</b>	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.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. <b>Developing and using models:</b> 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 worlds. <ul style="list-style-type: none"> <li>• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</li> </ul> </li> <li>3. Planning and carrying out investigations</li> <li>4. Analyzing and interpreting data</li> <li>5. Using mathematics and computational thinking</li> <li>6. Constructing explanations and designing solutions</li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>WEATHER AND CLIMATE</b></p> <p>Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS.ESS2D.b)</p> <p>Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS.ESS2D.c)</p>	<p><b>ENERGY AND MATTER</b></p> <p>The total amount of energy and matter in closed systems is conserved.</p>

## EARTH'S SYSTEMS

<p><b>Performance Expectation</b></p>	<p>Construct an argument based on evidence about the simultaneous coevolution of Earth systems and life on Earth.</p>
<p><b>Clarification Statement</b></p>	<p>Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.</p>

<p><b>Science &amp; Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>	<p><b>Crosscutting Concepts</b></p>
<ol style="list-style-type: none"> <li>Asking questions and defining problems</li> <li>Developing and using models</li> <li>Planning and carrying out investigations</li> <li>Analyzing and interpreting data</li> <li>Using mathematics and computational thinking</li> <li>Constructing explanations and designing solutions</li> <li><b>Engaging in argument from evidence:</b> 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. <ul style="list-style-type: none"> <li>Construct an oral and written argument or counterarguments based on data and evidence.</li> </ul> </li> <li>Obtaining, evaluating, and communicating information</li> </ol>	<p><b>WEATHER AND CLIMATE</b> Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS.ESS2D.b)</p> <p><b>BIOGEOLOGY</b> 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. (HS.ESS2E.a)</p>	<p><b>STABILITY AND CHANGE</b> Much of science deals with constructing explanations of how things change and how they remain stable.</p>

## HUMAN SUSTAINABILITY

<b>Performance Expectation</b>	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.
<b>Clarification Statement</b>	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.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<ol style="list-style-type: none"> <li>Asking questions and defining problems</li> <li>Developing and using models</li> <li>Planning and carrying out investigations</li> <li>Analyzing and interpreting data</li> <li>Using mathematics and computational thinking</li> <li><b>Constructing explanations and designing solutions:</b> Constructing explanations (science) and designing solutions (engineering) 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. <ul style="list-style-type: none"> <li>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.</li> </ul> </li> <li>Engaging in argument from evidence</li> <li>Obtaining, evaluating, and communicating information</li> </ol>	<p><b>NATURAL RESOURCES</b> Resource availability has guided the development of human society. (HS.ESS3A.a)</p> <p><b>NATURAL HAZARDS</b> 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.ESS3B.a)</p>	<p><b>CAUSE AND EFFECT</b> Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</p>

## HUMAN SUSTAINABILITY

<p><b>Performance Expectation</b></p>	<p>Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.</p>
<p><b>Clarification Statement</b></p>	<p>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 (coal, tar sands, and oil shales), and pumping (ground water, petroleum and natural gas). Science knowledge indicates what can happen in natural systems--not what should happen.</p>

<p><b>Science &amp; Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>	<p><b>Crosscutting Concepts</b></p>
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. Developing and using models</li> <li>3. Planning and carrying out investigations</li> <li>4. Analyzing and interpreting data</li> <li>5. Using mathematics and computational thinking</li> <li>6. <b>Constructing explanations and designing solutions:</b> Constructing explanations (science) and designing solutions (engineering) 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. <ul style="list-style-type: none"> <li>• Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.</li> </ul> </li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>NATURAL RESOURCES</b> 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.ESS3A.b)</p> <p><b>DESIGNING SOLUTIONS TO ENGINEERING PROBLEMS</b> 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. (HS.ETS1B.a)</p>	<p><b>SYSTEMS AND SYSTEM MODELS</b> Systems can be designed to do specific tasks.</p>

## HUMAN SUSTAINABILITY

<b>Performance Expectation</b>	Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
<b>Clarification Statement</b>	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.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. Developing and using models</li> <li>3. Planning and carrying out investigations</li> <li>4. Analyzing and interpreting data</li> <li>5. <b>Using mathematics and computational thinking:</b> 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 (e.g. trigonometric, exponential and logarithmic) 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. <ul style="list-style-type: none"> <li>• Create a computational model or simulation of a phenomenon, designed device, process, or system</li> </ul> </li> <li>6. Constructing explanations and designing solutions</li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>HUMAN IMPACTS ON EARTH SYSTEMS</b> The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS.ESS3C.a)</p>	<p><b>STABILITY AND CHANGE</b> Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</p>

## HUMAN SUSTAINABILITY

<b>Performance Expectation</b>	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
<b>Clarification Statement</b>	Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. Developing and using models</li> <li>3. Planning and carrying out investigations</li> <li>4. Analyzing and interpreting data</li> <li>5. Using mathematics and computational thinking</li> <li>6. <b>Constructing explanations and designing solutions:</b> Constructing explanations (science) and designing solutions (engineering) 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.               <ul style="list-style-type: none"> <li>• 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</li> </ul> </li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>HUMAN IMPACTS ON EARTH SYSTEMS</b> Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS.ESS3C.b)</p> <p><b>DESIGNING SOLUTIONS TO ENGINEERING PROBLEMS</b> 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. (HS.ETS1B.a)</p>	<p><b>STABILITY AND CHANGE</b> Feedback (negative or positive) can stabilize or destabilize a system.</p>

## HUMAN SUSTAINABILITY

<p><b>Performance Expectation</b></p>	<p>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.</p>
<p><b>Clarification Statement</b></p>	<p>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).</p>

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. Developing and using models</li> <li>3. Planning and carrying out investigations</li> <li>4. <b>Analyzing and interpreting data:</b> 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 <ul style="list-style-type: none"> <li>• 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.</li> </ul> </li> <li>5. Using mathematics and computational thinking</li> <li>6. Constructing explanations and designing solutions</li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>GLOBAL CLIMATE CHANGE</b> 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.ESS3D.a)</p>	<p><b>STABILITY AND CHANGE</b> Change and rates of change can be quantified and modeled over very short or long periods of time. Some system changes are irreversible.</p>

## HUMAN SUSTAINABILITY

<p><b>Performance Expectation</b></p>	<p>Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.</p>
<p><b>Clarification Statement</b></p>	<p>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.</p>

<p><b>Science &amp; Engineering Practices</b></p>	<p><b>Disciplinary Core Ideas</b></p>	<p><b>Crosscutting Concepts</b></p>
<ol style="list-style-type: none"> <li>Asking questions and defining problems</li> <li>Developing and using models</li> <li>Planning and carrying out investigations</li> <li>Analyzing and interpreting data</li> <li><b>Using mathematics and computational thinking:</b> 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 (e.g. trigonometric, exponential and logarithmic) 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. <ul style="list-style-type: none"> <li>Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.</li> </ul> </li> <li>Constructing explanations and designing solutions</li> <li>Engaging in argument from evidence</li> <li>Obtaining, evaluating, and communicating information</li> </ol>	<p><b>WEATHER AND CLIMATE</b> 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. (HS.ESS2D.d)</p> <p><b>GLOBAL CLIMATE CHANGE</b> Important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities (e.g., through computer simulations and other discoveries satellite imagery). (HS.ESS3D.b)</p>	<p><b>SYSTEMS AND SYSTEM MODELS</b> 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.</p>