



Grades 9-12

Earth & Space Science Curriculum Framework

Introduction

Science, Technology & Engineering, and Environmental Literacy & Sustainability (STEELS) Standards guide the study of the natural and human-made world through inquiry, problem-solving, critical thinking, and authentic exploration. This document displays a curriculum framework for **Grades 9-12 Earth & Space Science**. It is designed to focus curriculum and teaching, provide guidance for multiple approaches to curriculum development, encourage less reliance on textbooks as curriculum, and avoid activity-oriented teaching without focus/purpose.

Science Long Term Transfer Goals

In support of the Curriculum Framework, Long Term Transfer Goals (LTTG) provide the overarching practices that ground the foundation for a robust curriculum; thus, all curricula should relate to one or more of the LTTGs detailed below – as they highlight the effective uses of understanding, knowledge, and skill that we seek in the long run; i.e., what we want students to be able to do when they confront new challenges – both in and outside of school.

Students will be able to engage as scientifically literate members of a global society, using their learning to:

1. Approach science as a reliable and tentative way of knowing and explaining the natural world and designed world.
2. Weigh evidence and use scientific approaches to ask questions, investigate, and make informed decisions.
3. Make and use observations to analyze relationships and patterns in order to explain phenomena, develop models, and make predictions.
4. Evaluate systems, in order to connect how form determines function and how any change to one component affects the entire system.
5. Explain how the natural and designed worlds are interrelated and the application of scientific knowledge and technology can have beneficial, detrimental, or unintended consequences.

The Universe and Its Stars						
Key Understanding	Driving Question	Standard	Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary
Nuclear fusion powers the sun, and the sun changes over a predictable lifespan.	How does the Sun produce energy, and how will it change over time?	3.3.9-12.A Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation.	Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.	Scale Proportion and Quantity The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.	electromagnetic radiation nuclear fusion solar flare sunspot
Evidence shows that the universe has expanded and changed over time.	What evidence helps us explain how the universe began and has changed over time?	3.3.9-12.B Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, the motion of distant galaxies, and the composition of matter in the universe.	Constructing explanations and designing solutions Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gasses, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic	Energy and Matter Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems.	Big Bang Theory cosmic microwave background electromagnetic energy interstellar light spectra red shift universe

				<p>energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.</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.</p>		
Elements in the universe were produced in stars over their life cycle.	How are different elements produced over a star's life cycle?	3.3.9-12.C Communicate scientific ideas about the way stars, over their life cycle, produce elements.	Obtaining, Evaluating, and Communicating Information Communicate scientific ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	<p>The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.</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.</p>	Energy and Matter In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.	<p>atomic nuclei</p> <p>element</p> <p>helium</p> <p>hydrogen</p> <p>nucleosynthesis</p> <p>supernova</p>

Earth and the Solar System						
Key Understanding	Driving Question	Standard	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary
Orbiting objects in the solar system move in predictable patterns.	How can we predict where orbiting bodies will be in the solar system?	3.3.9-12.D Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.	Using Mathematical and Computational Thinking Use mathematical or computational representations of phenomena to describe explanations.	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.	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).	elliptical path Kepler's laws of orbital motion Newton’s law of universal gravitation orbit satellite

Over varying time scales, changes in the flow of energy into, through, and out of Earth's systems can cause changes in climate.	What are the human and natural causes that impact the flow of energy into and out Earth's system?	3.3.9-12.E Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	Developing and Using Models Use a model to provide mechanistic accounts of phenomena.	<p>Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.</p> <p>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.</p> <p>The foundation for Earth's global climate systems is the Electromagnetic radiation from the sun, as well as its reflection, absorption, storage,</p>	Cause and Effect Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	climate electromagnetic radiation flow of energy intensity ocean circulation timescale
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				and redistribution among the atmosphere, ocean, and land systems, and this energy's reradiation into space.		
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The History of Planet Earth						
Key Understanding	Driving Question	Standard	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary
Using evidence from natural processes we see today, we can make inferences about the history of the Earth and the age of its rocks.	How do people reconstruct and date events in Earth's planetary history?	3.3.9-12.F 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.	Engaging in Argument from Evidence Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.	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. 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. 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.	Patterns Empirical evidence is needed to identify patterns	continental crust mid-oceanic ridge oceanic crust plate tectonics radioactive decay radiometric dating subduction
By studying changes to Earth's features, as well as other objects in the solar system, we can reconstruct Earth's early planetary history.	How can we determine the age and history of Earth?	3.3.9-12.G 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.	Constructing Explanations and Designing Solutions Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion	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. 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.	Stability and Change Much of science deals with constructing explanations of how things change and how they remain stable.	asteroid erosion lunar meteorite plate tectonics radioactive decay radiometric dating

Earth Materials and Systems						
Key Understanding	Driving Question	Standard	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary
Earth's interconnected systems create feedback loops that either amplify or reduce changes to the planet.	What evidence do we have to show that changes to Earth's surface impacts the atmosphere, biosphere and hydrosphere?	3.3.9-12.H Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems.	Analyzing and Interpreting Data Analyze data using computational models in order to make valid and reliable scientific claims.	Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.	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.	climate coastal erosion glacial ice greenhouse gas groundwater humidity sediment wetlands
Thermal convection inside Earth moves and cycles matter through the planet.	How do we know matter is cycled within the Earth's interior?	3.3.9-12.I Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. 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.	Energy and Matter Energy drives the cycling of matter within and between systems.	isotope magnetic field mantle radial layers radioactive decay seismic wave thermal convection

Plate Tectonics and Large-Scale System Interactions						
Key Understanding	Driving Question	Standard	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary
Earth's systems are connected, so a change in one system can cause changes in others.	How does a change in one Earth system affect the others?	3.3.9-12.J 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.	Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.	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	constructive forces destructive mechanisms spatial scale temporal scale
The Roles of Water in Earth's Surface Processes						
Key Understanding	Driving Question	Standard	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary
Water's unique physical and chemical properties affect Earth materials and drive many surface processes.	How do the properties of water cause it to change Earth's materials and surfaces?	3.3.9-12.K Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.	Planning and Carrying Out Investigations 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.	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.	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.	chemical weathering density deposition frost wedging hydrologic cycle mechanical weathering solubility viscosity

Weather and Climate						
Key Understanding	Driving Question	Standard	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary
Carbon cycles through Earth's systems, and changes in where carbon is stored can affect climate.	How does carbon move throughout the Earth's systems and how can changes in that movement affect climate?	3.3.9-12.L Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.	Energy and Matter The total amount of energy and matter in closed systems is conserved.	atmosphere biosphere geosphere hydrosphere
Human activity impacts all of Earth's interacting spheres in ways that can be illustrated using computational models.	In what ways do the human impacts to one system result in changes in other systems?	3.3.9-12.M Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	Using Mathematics and Computational Thinking Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.	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. Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.	Systems and System Models When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.	atmosphere biosphere cryosphere geosphere Global Climate Models hydrosphere

Key Understanding	Driving Question	Standard	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary
By analyzing climate data and models, we can predict future temperature and precipitation changes and their impacts on Earth's systems.	How do we use past and present climate data to make predictions about future climate?	3.3.9-12.S 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.	Analyzing and Interpreting Data Analyze data using computational models in order to make valid and reliable scientific claims.	Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.	Stability and Change Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.	climate model outputs glacial ice volume precipitation sea level
Biogeology						
Key Understanding	Driving Question	Standard	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary
The feedback between the biosphere and other Earth's systems causes a continual co-evolution of the Earth's surface and life on Earth.	How have living things and Earth's nonliving systems changed each other over time, and what evidence shows us that these changes continue today?	3.3.9-12.N Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.	Engaging in Argument from Evidence Construct an oral and written argument or counter-arguments based on data and evidence.	Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.	Stability and Change Much of science deals with constructing explanations of how things change and how they remain stable.	atmosphere biosphere coevolution feedback photosynthesis

Natural Resources						
Key Understanding	Driving Question	Standard	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary
Resource availability, changes in climate and occurrence of natural hazards shape the development, location and size of human populations over time.	How do access to natural resources, safety from natural hazards and compatibility with climate features drive changes in human populations?	3.3.9-12.O 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.	Constructing Explanations and Designing Solutions 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.	Resource availability has guided the development of human society. 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.	Cause and Effect Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	human migration natural hazard natural resource
Key Understanding	Driving Question	Standard	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary

Cost-benefit ratios are used to evaluate solutions to minimize negative impacts of energy production and resource extraction.	When reducing, reusing and recycling of resources is not possible, how can we design solutions to minimize negative impacts?	3.3.9-12.P Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.	Engaging in Argument from Evidence 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).	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. 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.	Influence of Science, Engineering, and Technology on Society and the Natural World Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. Analysis of costs and benefits is a critical aspect of decisions about technology.	cost-benefit ratio mineral resources
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Human Impact on Earth Systems						
Key Understanding	Driving Question	Standard	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Vocabulary
The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources.	How can we use computer simulations to predict and sustainably manage natural resources?	3.3.9-12.Q Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.	Using Mathematics and Computational Thinking Create a computational model or simulation of a phenomenon, designed device, process, or system.	The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.	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	biodiversity natural resource sustainability
Human activities can have positive and negative impacts on natural systems.	How can we develop a technical solution that reduces the negative impacts of human activities on natural systems?	3.3.9-12.R Evaluate or refine a technological solution that reduces the impact of human activities on natural systems.	Constructing Explanations and Designing Solutions 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.	Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. 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.	Stability and Change Feedback (negative or positive) can stabilize or destabilize a system.	ecosystem degradation technological solution unintended consequences