2018 Virginia Science Standards of Learning

Curriculum Framework

Board of Education

Commonwealth of Virginia

Superintendent of Public Instruction
James F. Lane, Ed.D.

Assistant Superintendent of Learning
Gena Keller

Office of Science, Technology, Engineering, and Mathematics
Tina Manglicmot, Ed.D., Director
Anne Petersen, Ph.D., Science Coordinator
Joshua Bearman, Science Specialist
Myra Thayer, Science Specialist

NOTICE
The Virginia Department of Education does not discriminate on the basis of race, sex, color, national origin, religion, age, political affiliation, veteran status, or against otherwise qualified persons with disabilities in its programs and activities.

The *2018 Virginia Science Standards of Learning Curriculum Framework* can be found on the Virginia Department of Education's website at http://www.doe.virginia.gov/testing/sol/standards_docs/science/index.shtml.

Introduction

The *2018 Virginia Science Standards of Learning Curriculum Framework* amplifies the *Science Standards of Learning for Virginia Public Schools* (SOL) and defines the content knowledge, skills, and understandings that provide a foundation in science concepts and practices. The framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying enduring understandings and defining the essential science and engineering practices students need to master. This framework delineates in greater specificity the minimum content requirements that all teachers should teach and all students should learn.

School divisions should use the framework as a resource for developing sound curricular and instructional programs. This framework should not limit the scope of instructional programs. Additional knowledge and skills that can enrich instruction and enhance students' understanding of the content identified in the SOL should be included in quality learning experiences.

The framework serves as a guide for SOL assessment development. Assessment items may not and should not be a verbatim reflection of the information presented in the framework. Students are expected to continue to apply knowledge and skills from the SOL presented in previous grades as they build scientific expertise.

The Board of Education recognizes that school divisions will adopt a K–12 instructional sequence that best serves their students. The design of the SOL assessment program, however, requires that all Virginia school divisions prepare students to demonstrate achievement of the standards for elementary and middle school by the time they complete the grade levels tested. The high school end-of-course SOL tests, for which students may earn verified units of credit, are administered in a locally determined sequence.

Each topic in the framework is developed around the SOL. The format of the framework facilitates teacher planning by identifying the enduring understandings and the scientific and engineering practices that should be the focus of instruction for each standard. The categories of scientific and engineering practices appear across all grade levels and content areas. Those categories are: asking questions and defining problems; planning and carrying out investigations; interpreting, analyzing, and evaluating data; constructing and critiquing conclusions and explanations; developing and using models; and obtaining, evaluating, and communicating information. These science and engineering practices are embedded in instruction to support the development and application of science content.

Science and Engineering Practices

Science utilizes observation and experimentation along with existing scientific knowledge, mathematics, and engineering technologies to answer questions about the natural world. Engineering employs existing scientific knowledge, mathematics, and technology to create, design, and develop new devices, objects, or technology to meet the needs of society. By utilizing both scientific and engineering practices in the science classroom, students develop a deeper understanding and competence with techniques at the heart of each discipline.

Engineering Design Practices

Engineering design practices are similar to those used in an inquiry cycle; both use a system of problem solving and testing to come to a conclusion. However, unlike the inquiry cycle in which students ask a question and use the scientific method to answer it, in the engineering and design process, students use existing scientific knowledge to solve a problem. Both include research and experimentation; however, the engineering design process has a goal of a solving a societal problem and may have multiple solutions. More information on the engineering and design process can be found at https://www.eie.org/overview/engineering-design-process.

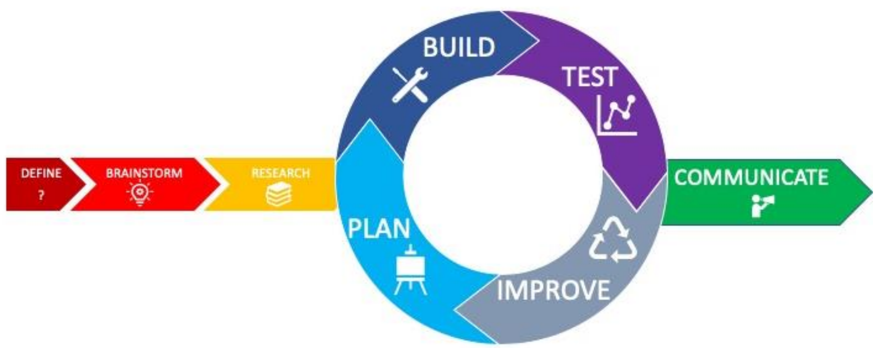

Figure 1: Engineering Design Process image based on the National Aeronautics and Space Administration (NASA) engineering design model.

The Engineering Design Process:

- Define: Define the problem, ask a question
- Imagine: Brainstorm possible solutions
- Research: Research the problem to determine the feasibility of possible solutions
- Plan: Plan a device/model to address the problem or answer the question
- Build: Build a device/model to address the problem or answer the question
- Test: Test the device/model in a series of trials
    - Does the design meet the criteria and constraints defined in the problem?
        - Yes? Go to Share (#8)
        - No? Go to Improve (#7)
- Improve: Using the results of the test, brainstorm improvements to the device/model; return to #3
- Share: Communicate your results to stakeholders and the public

Computational Thinking

The term *computational thinking* is used throughout this framework. Computational thinking is a way of solving problems that involves logically organizing and classifying data and using a series of steps (algorithms). Computational thinking is an integral part of Virginia's computer science standards and is explained as such in the *Computer Science Standards of Learning*:

> *Computational thinking is an approach to solving problems that can be implemented with a computer. It involves the use of concepts, such as abstraction, recursion, and iteration, to process and analyze data, and to create real and virtual artifacts. Computational thinking practices such as abstraction, modeling, and decomposition connect with computer science concepts such as algorithms, automation, and data visualization. [Computer Science Teachers Association & Association for Computing Machinery]*

Students engage in computational thinking in the science classroom when using both inquiry and the engineering design process. Computational thinking is used in laboratory experiences as students develop and follow procedures to conduct an investigation.

Structure of the *2018 Virginia Science Standards of Learning Curriculum Framework*

The framework is divided into two columns: Enduring Understandings and Essential Knowledge and Practices. The purpose of each column is explained below.

Enduring Understandings
The Enduring Understandings highlight the key concepts and the big ideas of science that are applicable to the standard. These key concepts and big ideas build as students advance in their scientific and engineering understanding. The bullets provide the context of those big ideas at that grade or content level.

Essential Knowledge and Practices
Each standard is expanded in the Essential Knowledge and Practices column. What each student should know and be able to do as evidence of understanding of the standard is identified here. This is not meant to be an exhaustive list nor is a list that limits what is taught in the classroom. It is meant to be the key knowledge and practices that define the standard. Science and engineering practices are highlighted with a leaf bullet (see footer).

The *2018 Virginia Science Standards of Learning Curriculum Framework* is informed by the Next Generation Science Standards (https://www.nextgenscience.org/).

Earth Science

The Earth Science standards focus on the complex nature of the Earth system, including Earth's composition, structure, processes, and history; its atmosphere, fresh water, and oceans; and its environment in space as a set of complex, interacting, and overlapping systems. The standards emphasize the nature of science as students learn about the development of scientific thought about Earth and space. The standards stress the interpretation of maps, charts, tables, and profiles; the use of technology to collect, analyze, and report data; and the utilization of science skills in systematic investigation. Problem solving and decision making are integral parts of the standards, especially as related to the costs and benefits of utilizing Earth's resources. Mathematics and computational thinking are important as students advance in their scientific thinking.

Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

ES.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems

- **ask questions that arise from careful observation of phenomena, examination of a model or theory, or unexpected results, and/or to seek additional information**
- **determine which questions can be investigated within the scope of the school laboratory or field experience**
- **generate hypotheses based on research and scientific principles**
- **make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated**
- **define design problems that involve the development of a process or system with multiple components and criteria**

b) planning and carrying out investigations

- **individually and collaboratively plan and conduct observational and experimental investigations**
- **plan and conduct investigations to test design solutions in a safe and ethical manner including considerations of environmental, social and personal impacts**

- **select and use appropriate tools and technology to collect, record, analyze, and evaluate data**

c) **interpreting, analyzing, and evaluating data**
- **construct and interpret data tables showing independent and dependent variables, repeated trials, and means**
- **construct, analyze, and interpret graphical displays of data, including scatterplots and line plots and consider limitations of data analysis**
- **apply mathematical concepts and processes to scientific questions**
- **use data in building and revising models, supporting explanations of phenomena, or testing solutions to problems**
- **analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims or determine an optimal design solution**

d) **constructing and critiquing conclusions and explanations**
- **make quantitative and/or qualitative claims based on data**
- **construct and revise explanations based on valid and reliable evidence obtained from a variety of sources, including students' own investigations, models, theories, simulations, peer review**
- **apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena or design solutions**
- **construct arguments or counter arguments based on data and evidence**
- **differentiate between a scientific hypothesis, theory, and law**

e) **developing and using models**
- **evaluate the merits and limitations of models**
- **develop, revise, and/or use models based on evidence to illustrate or predict relationships**
- **construct and interpret scales; diagrams; classification charts; graphs; tables; imagery; models; including geologic cross sections and topographic profiles**
- **read and interpret topographic and basic geologic maps and globes, including location by latitude and longitude**

f) **obtaining, evaluating, and communicating information**
- **compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem**
- **gather, read, and evaluate scientific and/or technical information from multiple sources, assessing the evidence and credibility of each source**
- **communicate scientific and/or technical information about phenomena and/or a design process in multiple formats**

Earth Science Content

ES.2 The student will demonstrate an understanding that there are scientific concepts related to the origin and evolution of the universe. Key ideas include:

a) the big bang theory is the current scientific explanation of the origin of universe;
b) stars, star systems, and galaxies change over long periods of time;
c) characteristics of the sun, planets, and their moons, comets, meteors, asteroids, and dwarf planets are determined by materials found in each body; and
d) evidence attained through space exploration has increased our understanding of the structure and nature of our universe.

Central Idea: By examining the characteristics and motion of objects within our universe, we can use scientific evidence to theorize how it was created and how it has evolved over time.

Vertical Alignment: Students study the distribution of matter throughout the solar system and as well as the organization of various celestial bodies in sixth grade (6.2). The spatial relationships, characteristics, and interactions among the various celestial bodies, and the role of gravity, are emphasized in Earth Science.

Enduring Understandings	**Essential Knowledge and Practices**
The big bang and solar nebular theories encapsulate our current understanding of the origin of the universe and the origin of stars and planetary systems. The development of these theories illustrates the nature of science. • The universe is a dynamic system of interacting components that is vast in size, still expanding, and about 13.8 billion years old (ES.2 a). • The big bang theory is our best current model for the development of the universe. The big bang theory states that the universe began in a very hot, dense state that expanded and eventually condensed into galaxies (ES.2 a).	In order to meet this standard, it is expected that students will • describe the big bang theory and provide evidence used to support the theory (ES.2 a) • compare the characteristics and evolution of more massive stars to that of the sun (ES.2 b) • relate Earth's ability to sustain life to the sun's current stage in its stellar evolution and proximity to the Earth (ES.2 b) • use the Hertzsprung-Russel diagram to classify stars and use this classification to determine the projected stellar life cycle (ES.2 b)

Enduring Understandings	Essential Knowledge and Practices
• The big bang theory is based on scientific evidence obtained through astronomical research, including evidence about the nature of light and the red shift, Hubble's law and the movement of distant objects, cosmic microwave background radiation, and the composition and abundance of elements from star and nebular spectra (ES.2 a). • Shortly after the big bang, the very lightest elements (lowest atomic number), predominantly hydrogen and helium, were formed. Stars of all sizes initially fuse this hydrogen to helium; however, the mass of a star determines what other fusion products it will create during the remainder of its lifetime. Stars that are several times more massive than the sun produce heavier elements, up to iron. The largest stars at the end of their lives become supernovae. In those highly energetic explosions in the presence of abundant neutrons, the heaviest natural elements are created (ES.2 a). • The solar nebular theory is science's best current idea for the formation of stars and planetary systems. The nebular theory explains that stars form through the condensation of the nebula. Photographic images show likely examples of stellar nurseries and star formation within the galaxy (i.e., Crab Nebula) (ES.2 b). • Stars have finite lifetimes and go through changes over time. The mass of a star controls its evolution, lifespan, and fate. Stars form by condensation and gravitational compression of interstellar gas and dust (ES.2 b). • The Hertzsprung-Russell diagram illustrates the relationship between the absolute magnitude or luminosity of a star and	• analyze the variations in chemical compositions of stars of different masses and relate to the process of fusion and the star's stage in its stellar evolution (ES.2 b) • understand the connection between fusion of elements in stars and the presence and abundance of elements that make up our solar system and its contents, including living organisms (ES.2 b) • analyze recent research findings (i.e., from NASA) about the terrestrial and gaseous planets; compare their atmospheres, internal composition, surface conditions, size, and rotation; and interpret why each planet has such characteristics as related to nebular theory (ES.2 b, c) • compare the classification of the dwarf planet Pluto to the planets in relation to its orbit, and its similarity to other objects in the Kuiper Belt (ES.2 c) • compare the defining characteristics among moons, comets, meteoroids, and asteroids (ES.2 c) • describe how technology (e.g., Galileo's telescope, Hubble telescope, planetary orbiters, landers/rovers) has contributed to our scientific understanding of the cosmos (ES.2 d).

Enduring Understandings	Essential Knowledge and Practices
the surface temperature of stars. As stars age, their position on the Hertzsprung-Russell diagram changes (ES.2 b). The solar system is a set of interrelated and interdependent components that are seamlessly connected through the flow of matter and energy. Characteristics of these components within the solar system are determined by their composition. • Galaxies are collections of billions of stars (ES.2 b). • The solar system is in the Milky Way galaxy (ES.2 b). • There are essentially two types of planets in our solar system. The four inner (terrestrial) planets consist mostly of rocky outer layers and have cores of metallic elements. The four outer planets are gas giants, consisting mostly of hydrogen and helium. The nature of the gas planets' interiors is subject to ongoing research (ES.2 c). • The dwarf planet, Pluto, is about two-thirds the diameter of Earth's moon and probably has a rocky core surrounded by a mantle of water ice. It is part of the Kuiper Belt (ES.2 c). • Moons are natural satellites of planets that vary widely in composition and in method of formation (ES.2 c). • Comets orbit the sun and consist mostly of frozen gases (ES.2 c). • There are countless fragments comprised of rock and dust floating throughout the solar system. Those that enter Earth's atmosphere are known as meteors. Meteors that are large enough to pass through the atmosphere contain information regarding the age, composition, and evolution	

Enduring Understandings	Essential Knowledge and Practices
of our solar system, as well as potential signs of life having developed extra-terrestrially (ES.2 c). • Asteroids are usually leftover debris from the formation of the solar system, or creations from the collisions of other asteroids (ES.2 c). • Technological advances, breakthroughs in interpretation, and new observations continuously refine our understanding of Earth and the solar system (ES.2 d). *Students are not responsible for describing the contributions of specific scientists or space missions.* • Much of our knowledge about the solar system is a result of space exploration efforts. These efforts continue to improve our understanding of the solar system. For example, ongoing research including information about magnetic and gravitational fields, surface features, volcanism, tectonics, atmospheric composition, and overall density reveals much about planets' internal structures, formation, and evolution (ES.2 d). *Students are not responsible for describing the contributions of specific scientists or space missions.* • A light-year is the distance light travels in one year and is the most commonly used measurement for distance in astronomy (ES.2 d). • Much of the information about our galaxy and the universe comes from ground-and space-based observations across the electromagnetic spectrum. Information about other planets comes from observations and measurements from Earth's surface; space telescopes; and interplanetary missions including landers, flybys, and orbiting spacecraft (ES.2 d).	

Enduring Understandings	Essential Knowledge and Practices
Students are not responsible for describing the contributions of specific scientists or space missions.	

ES.3 The student will investigate and understand that Earth is unique in our solar system. Key ideas include
a) Earth supports life because of its relative proximity to the sun and other factors; and
b) the dynamics of the sun-Earth-moon system cause seasons, tides, and eclipses.

Central Idea: The accretion of nebular materials to form our solar system in its precise location and with its specific characteristics gives it the unique ability to foster past and current lifeforms on Earth. The location and characteristics also are responsible for observable, systemic interactions.

Vertical Alignment: Students are introduced to the cause-and-effect relationships of the motion and position of the sun, Earth, and moon as it pertains to the moon phases, seasons, and tides in sixth grade science (6.3). These concepts and interactions are investigated further in Earth Science.

Enduring Understandings	Essential Knowledge and Practices
The proximity of the Earth to the sun and moon in our solar system affects Earth systems and enables life to exist on Earth. • The solar system consists of many types of celestial bodies. Earth is the third planet from the sun and is located between the sun and the asteroid belt. It has one natural satellite, the moon. Water occurs on Earth as a solid (ice), a liquid, and a gas (water vapor), due to Earth's position in the solar system (ES.3 a). • The sun consists largely of hydrogen gas. Its energy comes from nuclear fusion of hydrogen to helium (ES.3 a).	In order to meet this standard, it is expected that students will • explain the role of the position of Earth in the solar system, the size of Earth and sun, Earth's axial tilt, and the presence of a large moon, in affecting the planet's evolution and life forms (ES.3 a) • predict what conditions would need to be in place for another celestial object to support life (ES.3 a) • create a 3-D scale model of Earth and the orbiting moon and explain the progression of moon phases (ES.3 b) • relate the moon's orbit and tilt to type and frequency of eclipses (ES.3 b)

Enduring Understandings	Essential Knowledge and Practices

The interactions and orientations of the sun, Earth, and moon lead to patterns that are evidenced in seasons, eclipses, and the phases of the moon.
• Earth revolves around the sun while tilted on its axis. The axial tilt is responsible for the incidence and duration of sunlight striking a given hemisphere that varies during the Earth's revolution around the sun, thus causing seasons. Equinoxes and solstices represent distinct, quarterly points signaling the cyclic change of seasons (ES.3 b).
• The moon revolves around Earth, creating moon phases and eclipses. Solar eclipses occur when the moon blocks sunlight from Earth's surface, while lunar eclipses occur when Earth blocks sunlight from reaching the moon's surface (ES.3 b).
• The tides are the periodic rise and fall of water level caused by the gravitational pull of the sun and moon (ES.3 b).
• Grid systems of latitude and longitude are used to define locations and directions on maps, globes, and charts (ES.3).
• Lines of latitude (parallels) run east-west and increase from 0° at the Equator to 90°at the poles. The Equator represents the center of the Earth, where the sun appears to pass directly overhead on the spring and fall equinoxes. The Earth bulges slightly at the equator. Lines of latitude are spaced equally apart and never intersect (ES.3). *Students are not responsible for memorizing the names or values of specific latitude lines.*
• Lines of longitude run north to south and are not parallel, intersecting at the poles. As opposed to latitude lines, which
	• create a model showing the positions of the Earth, moon, and sun during a solar and lunar eclipse (ES.3 b)
	• explain why solar and lunar eclipses do not occur each month (ES.3 b)
	• read and interpret maps, using latitude and longitude coordinates, to
	  o locate landmarks and geographic features
	  o examine the significance of certain lines of latitude (Tropics of Cancer & Capricorn, Arctic & Antarctic Circles, Equator, and poles) in representing the sun-Earth relationship (ES.3 b).

Enduring Understandings	Essential Knowledge and Practices
are determined by natural phenomena, longitude lines were determined arbitrarily, with the Prime Meridian (0°) running through Greenwich, England and 180° representing the International Date Line (ES.3).	

ES.4 The student will investigate and understand that there are major rock-forming and ore minerals. Key ideas include
a) analysis of physical and chemical properties supports mineral identification;
b) characteristics of minerals determine the uses of minerals; and
c) rock-forming minerals originate and are formed in specific ways.

Central Idea: Minerals can be identified by multiple characteristics, including atomic structure. These characteristics determine the use of the minerals.

Vertical Alignment: Students learn that there are a limited number of elements that comprise the solid portion of planet Earth in sixth grade (6.5). The concept that these elements and compounds have unique physical and chemical properties, based on atomic composition and bonding, is introduced in eighth grade; however, this is not explicitly applied to Earth processes (PS.2, PS.3).

Enduring Understandings	Essential Knowledge and Practices
The structure of a mineral determines many of its properties and functions. The chemical and physical properties of minerals are used to classify minerals. *Students are not expected to recognize or identify specific minerals and their uses without a classification key.* • Earth materials take many different forms as they cycle through the geosphere (ES.4 a). • A mineral is a naturally occurring, inorganic, solid substance (at room temperature), with a definite chemical composition and a defined geometric arrangement of atoms	In order to meet this standard, it is expected that students will • relate the abundance of mineral-forming elements with the processes and conditions required to form them (ES.4 a) • identify minerals at or near Earth's surface and relate these to the Earth's general structure, plate tectonics, and chemical and physical weathering (ES.4 a) • relate how the structure and composition determine the properties of silicates, carbonates, and oxide minerals (ES.4 a)

Enduring Understandings	Essential Knowledge and Practices
(a crystalline structure). A mineral can be identified by its specific chemical and physical properties. The appearance and properties of the mineral can vary due to inclusion of other elements, rate of cooling/crystallization, and space (ES.4 a). • Different minerals have different internal arrangements of atoms, with certain minerals having planes of weaker bonds in one or more directions. When hit, some minerals may tend to break regularly along planes of weakness (ES.4 a). • The major elements found in Earth's crust are oxygen, silicon, aluminum, and iron (ES.4 a). • Silicate minerals are composed of silica tetrahedra (SiO_4^{-2}) that are organized in various patterns and frequently bonded with metal cations. Silicate minerals are the largest rock-forming group and comprise over 90 percent of crustal materials (ES.4 a). • The carbonate group of minerals is composed of the carbonate ion (CO_3^{-2}) and metal cations (ES.4 a). • The oxide group of minerals is composed of oxygen and a metal (ES.4 a). Minerals are suited for different uses. • Soil, rocks, and minerals provide essential materials for agriculture, manufacturing, and building (ES.4 b). • In Virginia, major rock and mineral resources include coal and natural gas, gravel and crushed stone, silica, titanium, and limestone (ES.4 b).	• relate cleavage patterns of minerals to atomic structure and bonding arrangement (ES.4 a) 🍃 plan and conduct an investigation to identify minerals based on their physical and chemical properties, such as hardness, color, luster, density (specific gravity), cleavage, fracture, streak, and effervescence (ES.4 a) • identify formation processes by attributes observed in rock-forming and ore mineral samples (ES.4 a) 🍃 utilize a table of mineral properties to identify and/or classify an unknown mineral (ES.4 a) • explain the uses and importance of ore minerals (ES.4 b) • describe the conditions needed to create large and small crystals (ES.4 c).

Enduring Understandings	Essential Knowledge and Practices

Within natural systems, the transfer of energy drives the cycling of matter. Both the transfer of energy and chemical composition play a role in the formation of different types of minerals.
• Minerals can form under a variety of conditions (ES.4 c). These conditions include
  o cooling of molten magma or lava
  o evaporation of liquids
  o cooling of saturated solutions (liquids)
  o high pressure and temperature.
• Minerals that form from lava tend to be very small because of the lava cooling quickly. Minerals that form from the cooling of magma are larger due to the relatively long cooling period (ES.4 c).	

ES.5 The student will investigate and understand that igneous, metamorphic, and sedimentary rocks can transform. Key ideas include
a) Earth materials are finite and transformed over time;
b) the rock cycle models the transformation of rocks;
c) layers of Earth have rocks with specific chemical and physical properties; and
d) plate tectonic and surface processes transform Earth materials.

Central Idea: Rocks transform through different processes that can be described by the rock cycle. The rock cycle is a model of the transformation of rocks and the actual process is affected by the Earth's conditions and may not be cyclical. Plate tectonics and surface processes transform Earth's materials.

Vertical Alignment: Students are introduced to the role of Earth's internal energy in moving the crust and transforming rocks through the theory of plate tectonics and the rock cycle in fifth grade (5.8). The concept is expanded in Earth Science, to include specifics on the processes as well as the physical and chemical properties of different types of rocks.

<table>
<tr><th>Enduring Understandings</th><th>Essential Knowledge and Practices</th></tr>
<tr><td>
Within natural and designed systems, it is possible to track the flow, cycles, and conservation of matter and energy. Earth materials take many different forms as they cycle through the geosphere.

The processes by which rocks are formed define the three major groups of rocks (ES.5 a).
The traditional rock cycle is a model that shows the processes by which all rocks are formed and shows how basic Earth materials are recycled through time. The rock cycle does not show the evolutionary nature of processes that yield the increased volume of less-dense, silica-rich rocks and continental crust over time (ES.5 b).
Rock material in the lithosphere (crust and upper mantle) is generally solid and relatively rigid. The rock of the deeper mantle may exhibit plastic flow but is not uniformly molten (ES.5 b).
Molten rock develops in the crust and mantle when

temperature is high enough to bring about partial melting
sudden reduction in pressure (as with faulting) allows melting
the presence of water (or other volatiles) reduces the melting point of the parent material (ES.5 b).

Magmas are highly associated with mid-ocean ridges and rift zones, subduction zones, and hot spots (ES.5 b).

Similarities and differences in chemical and physical properties can be used to sort and classify rocks. Students are
</td><td>
In order to meet this standard, it is expected that students will

explain how the model of the rock cycle demonstrates conservation of matter and energy (ES.5 a)
relate the size of igneous crystals (texture) with rate and location of cooling (ES.5 b)
model and interpret a vertical sequence of rocks and label the rock types and the related features in the sequence (ES.5 b)
describe characteristics of metamorphic and sedimentary rocks (ES.5 c)
classify rock types as igneous, metamorphic, or sedimentary (ES.5 c)
plan and conduct an investigation to identify an unknown rock sample based on chemical and physical characteristics (ES.5 c)
differentiate between clastic and non-clastic (chemical, and biological/organic) sedimentary rocks (ES.5 c)
compare distinguishing characteristics of the crystal structure and textures of extrusive and intrusive igneous rocks (ES.5 c)
differentiate between the structure of foliated and non-foliated metamorphic rocks (ES.5 c)
explain how surface processes and Earth's movement relate to rock formations and the availability of rock (ES.5 d).

</td></tr>
</table>

Enduring Understandings	Essential Knowledge and Practices
not expected to recognize or identify specific rocks and their uses without a classification key. • Rocks can be identified by mineral content and texture (ES.5 c). • Igneous rock forms from molten rock that cools and hardens either below or on Earth's surface. Extrusive igneous rocks most often have small or no crystals, resulting in fine-grained or glassy textures. Intrusive igneous rocks generally have larger crystals and a coarser texture. The composition and textures of igneous rocks provide detailed clues about their formation (ES.5 c). • Generally, clastic, sedimentary rocks are made up of fragments of other rocks (ES.5 c). • Sedimentary rocks may be formed by many different processes; thus, some rock types don't fit neatly into a standard classification, such as *clastic* or *chemical* (ES.5 c). • Chemical sedimentary rocks are formed through predominantly inorganic, chemical means (e.g., precipitation) (ES.5 c). • Biochemical or biological sedimentary rocks are formed from the stratified remains of plant material or carbonate-shelled organisms (ES.5 c). • Metamorphic rocks form when any rock is changed by the effects of heat, pressure, or chemical action. Foliation in metamorphic rocks includes slaty cleavage, schistosity, and mineral banding. Non-foliated metamorphic rocks have	

Enduring Understandings	Essential Knowledge and Practices
little or no mineral banding and are relatively homogenous (ES.5 c). Systems are comprised of interacting and interdependent elements that are subject to change in response to inputs and outflows of energy and matter. All Earth processes are the result of energy flowing and mass cycling within and among Earth's systems. • Weathered and unstable rock materials erode from some parts of Earth's surface and are deposited in others (ES.5 d). • Weathering, erosion, and deposition are interrelated processes that work with Earth's internal processes to alter the composition of rock material. Uplift and increased elevation caused by tectonic processes lead to increased erosion. Weathering is the process by which rocks are broken down chemically and physically by the action of water, air, and organisms. Erosion is the process by which Earth materials are physically incorporated into moving water, ice, or wind and transported. Deposition is the process by which Earth materials carried by wind, water, or ice settle out and are left in a location when energy levels decrease. The size of the material deposited is proportional to the available energy in the medium of transport (ES.5 d). • The large-scale plate tectonic processes (e.g., subduction, island arc formation, continental collisions, and orogeny) occurring at and near plate boundaries are responsible for significant transformations of Earth materials (ES.5 d).	

ES.6 The student will investigate and understand that resource use is complex. Key ideas include
a) global resource use has environmental liabilities and benefits;
b) availability, renewal rates, and economic impact are considerations when using resources;
c) use of Virginia resources has an impact on the environment and the economy; and
d) the selection of various energy sources has environmental and economic impacts.

Central Idea: Earth is our home; its resources mold civilizations, drive human exploration, and drive human endeavors that include art, literature, and science. Many factors affect the use and the conservation of natural resources to include availability, renewal rates, and economics. The use and allocation of these resources globally have economic, political, and environmental impacts.

Vertical Alignment: Students study the importance of managing and conserving natural resources as well as reducing environmental hazards in sixth grade science (6.9). In sixth grade, students also focus on the policy involved with the use and conservation of natural resources. In Earth Science, the focus shifts to the environmental and economic impacts of natural resource use.

Enduring Understandings	**Essential Knowledge and Practices**
Natural resources are materials with different properties and suited for different uses. Many natural resources are limited and are distributed unevenly around the planet. • Virginia has many natural resources, including those that are renewable and nonrenewable (ES.6 c). • Renewable resources can be replaced by nature at a rate close to the rate at which they are used. Renewable resources include vegetation, sunlight, and surface water (ES.6 a). • Nonrenewable resources are replenished very slowly by natural processes or not at all. Nonrenewable resources include coal, oil, and minerals (ES.6 a). Humans resource use has a cause-and-effect impact on Earth systems and on the global economy.	In order to meet this standard, it is expected that students will 🍃 construct an explanation based on evidence for how the availability of natural resources have influenced human activity (ES.6 a) • relate the formation of fossil fuels (coal and natural gas) in terms of the rock cycle to ancient biologic and atmospheric/climatic conditions and changes within Virginia (ES.6 b) 🍃 determine the sources of clean water in their community, analyze consumption and supply data, and forecast potential issues related to sustainability (ES.6 b) 🍃 analyze how Virginia's production and use of various natural resources has changed over the last 150 years (ES.6 c)

Enduring Understandings	**Essential Knowledge and Practices**
• Living standards include the use of both renewable and nonrenewable resources (ES.6 b). • Extraction and use of any resource carries an environmental cost that must be weighed against economic benefit (ES.6 b). • Earth scientists and engineers develop new technologies to extract resources while reducing the pollution, waste, and ecosystem degradation caused by extraction (ES.6 b). • Technologies that harness renewable energy still require an initial energy and materials investment, thus long-term cost-and-benefit analyses need to be considered (ES.6 b). • Clean water resources, while renewable, are directly affected by human activity through extraction and pollution (ES.6 b). • In Virginia, major rock and mineral resources include coal and natural_gas for energy, gravel and crushed stone for road and building construction, silica for electronics, zirconium and titanium for advanced metallurgy, and limestone for making concrete (ES.6 c). There are advantages and disadvantages to using any energy source. These advantages and disadvantages may affect the environment and have economic implications. • Fossil fuels are nonrenewable in human timescale, create carbon dioxide when burned, and may cause pollution, but are relatively cheap and easy to use once they are extracted. New sources of energy and methods of resource	• research and analyze various types of recent data (e.g., climate, agriculture, and biomass production) and evaluate Virginia's potential as a producer of renewable energy sources (ES.6 d) • assess the role of fossil fuels and renewable energy sources in the future and compare the environmental benefits and costs among the various options (ES.6 d) • analyze data concerning a range of emerging energy and mineral resources in Virginia in terms of costs and benefits and create an evidence-based forecast of trends and effects on the environment and economy (ES.6 d)

Enduring Understandings	Essential Knowledge and Practices
extraction, such as hydraulic fracturing, create new economic and environmental tradeoffs (ES.6 d). • Renewable energy resources include biomass, geothermal, hydropower, and solar and wind power. Although these are renewable resources, there are still costs and benefits associated with each type of energy (ES.6 d).	

ES.7 The student will investigate and understand that plate tectonic theory explains Earth's internal and external geologic processes. Key ideas include

a) convection currents in Earth's interior lead to the movement of plates, creation of the magnetic field, and the distribution of materials in Earth's layers;
b) features and processes occur within plates and at plate boundaries;
c) interaction between tectonic plates causes the development of mountain ranges and ocean basins; and
d) evidence of geologic processes is found in Virginia's geologic landscape.

Central Idea: The theory of plate tectonics is central to many Earth Science concepts as it explains how the structure of the Earth's crust and many associated phenomena result from the interaction of rigid lithospheric plates that move slowly over the underlying mantle.

Vertical Alignment: Students are introduced to the theory of plate tectonics in fifth grade as they describe the role of energy in the movement of plates and the resulting changes in the Earth's surface (5.8). The role of convection currents in the creation of Earth's magnetic field, the interactions resulting from plate movement, and the impact of these interactions on the crust is the focus of Earth Science.

Enduring Understandings	Essential Knowledge and Practices
Plate tectonic theory is a shared understanding that encapsulates our current understanding of geologic processes.	In order to meet this standard, it is expected that students will • use available data (seafloor age, magnetic information, seismic profiles, laser-measured motion studies, fossil

Enduring Understandings	Essential Knowledge and Practices
• Plate tectonic processes serve as the major driver of the transformations of rock materials represented in the traditional rock cycle. Plate tectonics drive the evolution of Earth’s surface features and materials by fractionating material by chemical, mineralogical, and physical properties (ES.7 a). • Earth’s interior is in constant motion through the process of convection (ES.7 a). • Earth consists of a solid, mostly iron inner core; a liquid, mostly iron outer core; a crystalline but largely plastic mantle; and a rocky, brittle crust (ES.7 a). • Earth's geomagnetic field is thought to be created as a result of electric currents generated by convection of molten iron and nickel in the outer core. Heat flow, Earth’s rotation, and the existence of a solid inner core influence the convection-driven dynamo (ES.7 a). • The geomagnetic field imprints a magnetic signature in crystallizing igneous rock, thus leaving information that can be used to determine the motion and latitude of the Earth’s crust over time. Scientific evidence shows that Earth's geomagnetic field reverses itself periodically (a). The cycling of energy and matter in Earth’s interior occurs through the process of convection and has important consequences for Earth’s surface. • Plate motion occurs due to convection in Earth’s mantle, including upwelling of material from the deep mantle in rift zones, the lateral movement of tectonic plates, and the	evidence, rock types, tectonic history) to support plate tectonics theory (ES.7 a) 🍃 analyze the scientific_evidence for plate motion, multiple continental collisions, and rifting events over the last billion years (ES.7 a) • comprehend and apply the details of plate tectonics theory to the formation of continents, mountain chains, island arcs, deep open trenches, earthquake zones, and continental and mid-ocean volcanism (ES.7 b) 🍃 model the composition and structure of the continental and oceanic lithosphere in terms of, topographic features, density, thickness, and rates of motion (ES.7 b) • compare different types plate boundaries and resulting features. Cite current examples of convergent, divergent, and transform boundaries (ES.7 b) 🍃 analyze data on the speed, behavior, and paths of different types of seismic waves and determine Earth layer composition, density, and viscosity (ES.7 b) 🍃 analyze field and laboratory evidence and construct an explanation for the various structures produced in convergent continental and oceanic plate boundaries (ES.7 c) • interpret the tectonic history of an area based on the sequences, structures, and type of rocks found in that area (ES.7 c) • compare the tectonic activity of the east coast and the west coast of North America (ES.7 b, c)

Enduring Understandings	Essential Knowledge and Practices
pull of sinking dense, old plates at subduction zones (ES.7 b). • Earth's tectonic plates consist of the rocky crust and uppermost mantle and move slowly in respect to one another (ES.7 b). • Earth's lithosphere is divided into plates that are in motion with respect to one another. The lithosphere is composed of the crust and upper portion of the mantle. There are two different types of lithospheres—oceanic and continental—that have very different physical and mineralogical characteristics. The ocean lithosphere is relatively thin, young, and dense. The continental lithosphere is relatively thick, old, and less dense (ES.7 b). • Most large scale, high-energy events of geologic activity (e.g., earthquakes, volcanoes, and mountain building) occur as a result of relative motion along plate boundaries (ES.7 c). • Relative plate motions and plate boundaries are convergent (subduction and continental collision), divergent (seafloor spreading), or transform. Major features of convergent boundaries include collision zones (folded and thrust-faulted mountains) and subduction zones (volcanoes and trenches). Major features of divergent boundaries include mid-ocean ridges, rift valleys, fissure volcanoes, and flood lavas. Major features of transform boundaries include strike-slip faults (ES.7 c). • All plate boundaries show earthquake activity of varying energy levels and depths (ES.7 c).	🍃 integrate the rock cycle with plate tectonics theory and determine how this is reflected in the geology of Virginia's five physiographic/geologic provinces (ES.7 a, c, d) 🍃 interpret landforms, water features, elevation and elevation changes, and other pertinent features on topographic maps (ES 7 c, d) 🍃 construct profiles from topographic contours (ES 7 c, d) • label on a map the physiographic provinces of Virginia (ES 7 d) • comprehend the topographic, rock-type and geologic-structural characteristics of each physiographic province of Virginia (ES.7 d) 🍃 analyze the geology of Virginia in terms of the rock structures, types, ages, and topography represented in the five physiographic provinces and reconstruct a geologic history (ES.7 d) • integrate and interpret the rock cycle, plate tectonics, and Virginia's geology (ES.7 d).

Enduring Understandings	Essential Knowledge and Practices
• A volcano is an opening where magma erupts onto Earth's surface as lava and/or other extrusive material. Most volcanic activity is associated with plate boundaries: subduction, rifting, or seafloor spreading. Hot spot volcanic activity, such as the volcanic islands of Hawaii, is exceptional in that it is not related to plate boundaries. A hot spot is thought to be derived from a deep, localized heat source known as a mantle plume, though there is some scientific debate on this (ES.7 c). • A fault is a break or crack in Earth's crust along which movement has occurred (ES.7 c). • Topographic maps and satellite imagery are 2-D models that provide information defining 3-D landforms. They contain extensive information related to geographic as well as human structures and changes to the land surface and are useful in understanding geologic processes (ES.7 c). Earth's rock and other materials provide a record of Earth's geologic movement over time. This history is evidenced in the features of the different provinces in Virginia; geologic processes produce characteristic structures and features. • Virginia has over a billion-year-long tectonic and geologic history (ES.7 d). • Virginia has five physiographic/geologic provinces produced by past episodes of tectonic activity and continuous geologic activity. The five physiographic provinces (landforms) correspond very closely, but not completely, to the geologic provinces (underlying rocks and structures) of the state (ES.7 d).	

Enduring Understandings	Essential Knowledge and Practices
◦ The Coastal Plain is a flat area composed of young, unconsolidated sediments underlain by older crystalline basement rocks. These layers of sediment were produced by erosion of the Appalachian Mountains and Piedmont and then deposited on the Coastal Plain when sea levels were higher in the past. ◦ The Piedmont is an area of rolling hills underlain by mostly ancient igneous and metamorphic rocks. The igneous rocks are the roots of volcanoes formed during ancient episodes of subduction that occurred before and during the formation of the Appalachian Mountains. ◦ The Blue Ridge is a high ridge separating the Piedmont from the Valley and Ridge Province. The billion-year-old igneous and metamorphic rocks of the Blue Ridge are the oldest in the state. ◦ The Valley and Ridge province is an area with long parallel ridges and valleys underlain by ancient folded and faulted sedimentary rocks. The folding and faulting of the sedimentary rocks occurred during a collision between Africa and North America. The collision, which occurred in the late Paleozoic era, produced the Appalachian Mountains. ◦ The Appalachian Plateau has rugged, irregular topography and is underlain by ancient, flat-lying sedimentary rocks. The area is actually a series of plateaus separated by faults and erosional down-cut valleys. Most of Virginia's coal resources are found in the plateau province.	

ES.8 The student will investigate and understand that freshwater resources influence and are influenced by geologic processes and activities of humans. Key ideas include

a) water impacts geologic processes including soil development and karst topography;
b) the nature of materials in the subsurface affect the water table and future availability of fresh water;
c) weather and human usage impact freshwater resources, including water locations, quality, and supply; and
d) **stream processes and dynamics impact the major watershed systems in Virginia, including the Chesapeake Bay and its tributaries**.

Central Idea: Earth is a water planet; it is found everywhere on Earth from the heights of the atmosphere to the depths of the mantle. Although 70 percent of the planet's surface is covered in water, only 2.5 percent is in the form of freshwater. Water not only impacts geologic processes, but the limited amount of freshwater indicates it is a resource that must be conserved.

Vertical Alignment: The importance of water and its properties is studied throughout K-12 science. Students study the properties of water and water's role in weathering, moderating climate, agriculture, power generation, and public health in sixth grade (6.6, 6.8). In Earth Science, the focus is on freshwater resources and their impact on geologic processes.

Enduring Understandings	**Essential Knowledge and Practices**
Systems are comprised of interacting and interdependent elements that are subject to change in response to inputs and outflows of energy and matter. Freshwater is a component of the Earth system and is critical to geologic and life processes. • Freshwater is less than 3 percent of the Earth's surface (ES.8 a). • Earth's fresh water supply is finite. Geological processes, such as erosion, and human activities, such as waste disposal, can pollute water supplies (ES.8 a). • Earth's water cycles among the reservoirs of the atmosphere, streams, lakes, ocean, glaciers, groundwater, and deep interior of the planet (ES.8 a). • Water is continuously being passed through the hydrologic cycle. Fresh water is necessary for survival and most human activities (ES.8 a).	In order to meet this standard, it is expected that students will 🍃 interpret a hydrologic cycle diagram, including evaporation, condensation, precipitation, transpiration, infiltration, underground storage, and runoff (ES.8 a) • examine the formation of karst in terms of rock type, solubility and permeability, uplift, the water table, and chemical and physical weathering (ES.8 a) 🍃 interpret a simple groundwater diagram showing the zone of aeration, the zone of saturation, the water table, and an aquifer (ES.8 b) • examine the presence of groundwater in various types of rock terrains, including areas found in each of the physiographic/geologic provinces of Virginia (ES.8 b) 🍃 gather and synthesize information about groundwater issues (groundwater withdrawal, recharge rates, salt water

Enduring Understandings	Essential Knowledge and Practices
• Permeability is a measure of the ability of a rock or sediment to transmit water or other liquids. Water does not pass through impermeable materials. A substantial amount of water is stored in permeable soil and rock underground (ES.8 b). • Soil is formed from the weathering of rocks and organic activity and is composed of loose rock fragments and clay derived from weathered rock mixed with organic material (ES.8 a). • Karst topography is developed in areas underlain by carbonate rocks, including limestone and dolomite. Karst topography includes features like caves and sinkholes and forms when limestone is slowly dissolved away by slightly acidic groundwater. Where limestone is abundant in the Valley and Ridge province of Virginia, karst topography is common (ES.8 a). Human actions and geologic processes affect the availability of freshwater resources. • Humans affect the quality, availability, and distribution of Earth's water through modifications of streams, lakes, and groundwater (ES.8 c). • The flow of surface water shapes landscapes and causes changes in topography over time (ES.8 d). • Rivers (streams) continuously alter the landscape, eroding their channels downward toward base level and cutting back and forth into their sides, which slowly widens the valleys through which they flow. Broad, relatively flat areas adjacent to the river, floodplains, are produced over time. The confluence of smaller tributaries continually adds	intrusion, septic migration, chemical waste leakage, land subsidence), and describe potential consequences, including short- and long-term availability of the resource (ES.8 b) • plan and conduct an investigation to determine the effects of human activities on local freshwater sources (ES.8 c) • use data to identify a freshwater problem in the community and propose a solution(s) (ES.8 c) • locate the major Virginia watershed systems (i.e., Chesapeake Bay, Gulf of Mexico, and North Carolina sounds) on a map (ES.8 d) • utilize topographic maps, to trace and delineate a Virginia watershed utilizing geologic and topographic evidence (ES.8 d).

Enduring Understandings	Essential Knowledge and Practices
water, dissolved substances, and sediment to the river (ES.8 d). • Rivers carry a range of sediments (including organic debris) that settles out depending on the particle size and density of the material. During times of high flow, streams often spill out onto their floodplains, depositing sediments, and in the process, building up natural levees along their banks (ES.8 d). • Rivers with broad floodplains often move in a meandering fashion characterized by broad wave-like curves and arched, cut-off channels (oxbows). The lower energy of slowly-moving rivers allows small-grained sediments such as fine silt and clays to be carried in suspension with some bed load of coarser material (ES.8 d). • The three major regional watershed systems in Virginia lead to the Chesapeake Bay, the North Carolina sounds, and the Gulf of Mexico (ES.8 d). • As rivers near their mouths, such as those flowing into the Chesapeake Bay or the Gulf of Mexico, much of that sediment is deposited. Excessive sediment and dissolved nutrients may damage ecosystems (ES.8 d). • Stream processes that impact watershed systems include stream velocity and discharge. Stream dynamics include the process of receiving or losing water from the groundwater, flood erosion, and deposition (ES.8 d).	

ES.9 The student will investigate and understand that many aspects of the history and evolution of Earth and life can be inferred by studying rocks and fossils. Key ideas include

a) traces and remains of ancient, often extinct, life are preserved by various means in sedimentary rocks;
b) superposition, cross-cutting relationships, index fossils, and radioactive decay are methods of dating rocks and Earth events and processes;
c) absolute (radiometric) and relative dating have different applications but can be used together to determine the age of rocks and structures; and
d) rocks and fossils from many different geologic periods and epochs are found in Virginia.

Central Idea: Life evolves on a dynamic Earth and continuously modifies Earth.

Vertical Alignment: In fifth grade, students are introduced to the use of fossils and geologic patterns to provide evidence of Earth's change (Standard 5.9). Evidence to support the history of Earth and its changes, including fossil evidence, is the focus of Earth Science.

Enduring Understandings	Essential Knowledge and Practices
Earth's rocks and fossils document the existence, diversity, extinction, and change of many life forms and their environmental though Earth's history. • The history of Earth and the ages of rocks can be investigated and understood by studying rocks and fossils (ES.9 a). • Evidence of ancient, often extinct life is preserved in many sedimentary rocks. A fossil is the remains, impression, or other evidence preserved in rock of the former existence of life. Fossil evidence indicates that life forms have changed and become more complex over geologic time. Some ways in which fossils can be preserved are molds, casts, and original bone or shell (ES.9 a). Technological advances, breakthroughs in interpretation, and new observations continuously refine our understanding of Earth.	In order to meet this standard, it is expected that students will • describe how life has changed and become more complex over geologic time (ES.9 a) • explain short- and long-term global occurrences and assess proposed explanations as related to mass extinctions (short-term occurrences include asteroid/comet impacts, volcanism, earthquakes; long-term occurrences include continental collisions, climate collapse, global glaciation) (ES.9 a) • using a geologic history diagram (cross section) sequence the order of events from oldest to youngest and identify cross-cutting relationships (ES.9 b) • analyze data and graphs concerning the ratio of parent isotopes to daughter decay products present in a rock to calculate the age of the material based on absolute dating, and assess how radioactive decay provides a reliable

Enduring Understandings	Essential Knowledge and Practices
• Relative time places events in a sequence without assigning any numerical ages. Fossils, superposition, and cross-cutting relations are used to determine the relative ages of rocks (ES.9 b). • Absolute time places a numerical age on an event. Radiometric dating is used to determine the absolute age of rocks by measuring the products of radioactive decay of certain elements (ES.9 c). Explanations of stability and change in natural systems can be constructed by examining changes over time. Evidence, in the form of rocks and fossils from different geologic periods and epochs, has been found in Virginia. • In Virginia, fossils are found mainly in the Coastal Plain, Valley and Ridge, and Appalachian Plateau provinces. Most Virginia fossils are of marine organisms. This indicates that large areas of the state have been periodically covered by seawater (ES.9 d). • Paleozoic, Mesozoic, and Cenozoic fossils are found in Virginia (ES.9 d).	method to determine the age of many types of organic and inorganic materials (ES.9 c) • analyze and interpret complex cross sections using both relative and absolute dating to sequence and define the geologic history of the section (ES.9 b, c) • analyze a sequence of rocks in terms of types, textures, composition, fossils, structural and weathering features to infer the history of the sequence over time (ES.9 a, b) • use index fossils to infer the geologic history of a complex cross section (ES.9 b) • analyzing rock and fossil evidence and other scientific data to depict an evolution of Earth's geologic, oceanic, and atmospheric conditions over time (ES.9 d).

ES.10 The student will investigate and understand that oceans are complex, dynamic systems and are subject to long- and short-term variations. Key ideas include

a) chemical, biological, and physical changes impact the oceans;
b) environmental and geologic occurrences affect ocean dynamics;
c) unevenly distributed heat in the oceans drives much of Earth's weather;
d) features of the sea floor reflect tectonic and other geological processes; and
e) human actions, including economic and public policy issues, impact oceans and the coastal zone including the Chesapeake Bay.

Central Idea: Oceans are dynamic systems that support life, affect weather, and help moderate temperatures on the planet. Both natural occurrences and human activities can disrupt the equilibrium of the system.

Vertical Alignment: Students study water as applied to watershed systems in sixth grade. The effects of both biotic and abiotic factors on watershed health is introduced (6.8). In Earth Science, the focus is on oceans as systems.

Enduring Understandings	**Essential Knowledge and Practices**
Ocean systems are comprised of interacting and interdependent elements that are subject to change in response to inputs and outflows of energy and matter. • The ocean is a dynamic system in which many chemical, biological, and physical changes are taking place (ES.10 a). • Upwellings brings cold, nutrient-rich water from the deep ocean to the surface and are areas of rich biological activity (ES.10 a). • The tides are the periodic rise and fall of water level caused by the gravitational pull of the sun and moon (ES.10 a). Environmental and geologic occurrences may lead to changes in ocean dynamics. • A significant amount of atmospheric CO_2 is naturally absorbed by the oceans. However, scientific evidence indicates that this amount is slowly increasing as the CO_2 levels in the atmosphere rise. Scientific observations have indicated potential negative impact on marine organisms with calcium carbonate skeletons and shells (ES.10 b). • Sea level falls when glacial ice caps grow and rises when the ice caps melt (ES.10 b).	In order to meet this standard, it is expected that students will • explain the role of oceans in the extraction of atmospheric carbon dioxide and the relation to the formation of carbonates (ES.10 a) • investigate trends of ocean temperature and pH over time as it relates to the extraction of CO_2 and the formation of carbonates (ES.10 a) • analyze the effects of changing ocean pH on marine organisms, carbon sequestration, and the production of atmospheric oxygen (ES.10 a) • analyze the environmental effects of oceanic disasters on the base of the food web; economics; and future productivity of the ocean environment (ES.10 b) • describe the relationship among moving continents, the presence of ice caps, and ocean circulation over long periods of time (ES.10 c) • relate important ocean conditions, including El Niño, and La Nina to weather on the continents (ES.10 c) • analyze the role of ocean currents in the distribution of heat from the equatorial regions to the poles, and predict what changes may occur as continents move and atmospheric conditions and climate vary (ES.10 c)

Enduring Understandings	Essential Knowledge and Practices
Systems are dynamic and change in response to inputs and outflows of energy and matter. Temperature differentials and the resulting transfer of energy within the oceans drive Earth's weather. • The ocean is the single largest reservoir of heat at Earth's surface. The stored heat in the ocean drives much of Earth's weather and causes climate near the ocean to be milder than climate in the interior of continents (ES.10 c). • Most waves on the ocean surface are generated by wind, the movement of air from high to low pressure, is caused by the uneven heating of Earth's surface by the sun (ES.10 c). • Convection is the major mechanism of energy transfer in the oceans, atmosphere, and Earth's interior (ES.10 c). • There are large current systems in the oceans that carry warm water toward the poles and cold water toward the equator (ES.10 c). The cycling of energy and matter in Earth's interior occurs through the process of convection and has important consequences for ocean topography. • The topography of the seafloor is at least as variable as that on the continents. Features of the seafloor that are related to plate tectonic processes include mid-ocean ridges and trenches (ES.10 d). The oceans' resources are finite and should be utilized with care. Human activities significantly change the rates of many of Earth's surface processes and alter the biosphere.	• analyze water temperatures during the yearly cycle, and relate this to the formation of storms (ES.10 c) • model the relationship between tectonic processes and the features of the sea floor (ES.10 d) • describe different types of pollution (e.g., sediment, toxins, fertilizer, salt water intrusion) that can pollute the Chesapeake Bay throughout its entire six-state watershed (ES.10 e) • identify the effects of human activities on the oceans (ES.10 e) • analyze reports, media articles, and other narrative materials related to the health of oceans or a local watershed system; propose a solution and analyze cost benefits to the implementation of the solution (ES.10 e).

Enduring Understandings	Essential Knowledge and Practices
• The oceans are an important source of food and mineral resources as well as a venue for recreation and transportation (ES.10 e). • Algae in the oceans are an important source of atmospheric oxygen (ES.10 a). • The oceans are environmentally and economically important. Human activities and public policy have important consequences for the oceans. The impact of human activities, such as waste disposal, construction, and agriculture, affect the water quality within watershed systems and ultimately the ocean. Pollution and overfishing can harm or deplete valuable resources (ES.10 e). • Estuaries, like the Chesapeake Bay, are areas where fresh and salt water mix, producing variations in salinity and high biological activity. Chemical pollution and sedimentation are great threats to the well-being of estuaries and oceans (ES.10 e).	

ES.11 The student will investigate and understand that the atmosphere is a complex, dynamic system and is subject to long- and short-term variations. Key ideas include

a) the composition of the atmosphere is critical to most forms of life;
b) biologic and geologic interactions over long and short time spans change atmospheric composition;
c) natural events and human actions may stress atmospheric regulation mechanisms; and
d) human actions, including economic and policy decisions, impact the atmosphere.

Central Idea: The atmosphere is a dynamic system that support life through retaining heat, blocking damaging rays, and provides gases needed for homeostasis. Both natural occurrences and human activities can disrupt the equilibrium of the system.

Vertical Alignment: Students investigate the atmosphere's composition and characteristics in sixth grade and study the effects of changes in altitude, thermal energy, and motion (6.7). In Earth Science, students study atmospheric interactions and examine the atmosphere as a complex system.

Enduring Understandings	**Essential Knowledge and Practices**
Earth's atmosphere is comprised of interacting and interdependent elements that are subject to change in response to inputs and outflows of energy and matter. • Earth's atmosphere is 21 percent oxygen, 78 percent nitrogen, and one percent trace gases. The composition of the atmosphere can change due to human, biologic, and geologic activity (ES.11 a). • The ability of Earth's atmosphere to absorb and retain heat is affected by the presence of gases like water vapor and carbon dioxide (ES.11 a). The cycling of energy and matter through various natural and manmade processes have led to changes in the composition of Earth's atmosphere. • Evolution, including the origination and extinction of species, has altered the composition of gases in the atmosphere (ES.11 b). • The composition of Earth's atmosphere has changed over geologic time. Earth's atmosphere is unique in the solar system in that it contains substantial oxygen (ES.11 b). • Earth's most primitive atmosphere may have been comprised of mainly helium and hydrogen~~.~~; however, it is unclear whether Earth had an atmosphere at its formation due to radiation from the young sun Scientific evidence suggests that Earth's early atmosphere contained mostly	In order to meet this standard, it is expected that students will • describe the role of different atmospheric components in supporting life (ES.11 a) • analyze atmospheric change over geologic time and assess the role and evidence of photosynthetic organisms in this transformation (e.g., ice cores, stromatolites, red beds) (ES.11 b) • explain how volcanic activity or meteor impacts could affect the atmosphere, and life on Earth (ES.11 c) • explain how biologic activity, including human activities, may influence global temperature and climate (ES.11 c) • research historical information and scientific data on the impact of major volcanic eruptions and other natural events on the atmosphere (ES.11 c) • research data on the effect of human activities and public policy on Earth's ozone layer since chlorofluorocarbons (CFC) were banned (ES.11 d) • research and analyze the effects of the development of fossil fuels and other human activity on atmospheric composition; develop a suggestive set of steps or sample policies to monitor and mitigate potential issues and concerns (ES.11 d).

Enduring Understandings	Essential Knowledge and Practices
CO_2, CO, nitrogen, SO_2, and water vapor, resulting from volcanic outgassing. This atmosphere was then modified by early photosynthetic life (ES.11 b). • The atmospheres of Earth, Mars, and Venus apparently had very different paths toward the evolution of their current conditions. Many factors may have influenced this, including distance from the sun, planetary mass, the nature of the planets' interiors, the presence of a large moon, and the origin and nature of each planet's early atmosphere (ES.11 b). • Early photosynthetic life such as cyanobacteria (blue-green algae) consumed carbon dioxide and generated oxygen. It was only after early photosynthetic life generated oxygen that animal life became possible (ES.11 b). Human activities and natural occurrences may significantly change the rates of many of Earth's atmospheric processes. • Interaction among Earth's spheres leads proportions of gases staying within ranges that support life. The biosphere interacts with other spheres in many ways including the carbon cycle, water cycle, and nitrogen cycle (ES.11 c). • Volcanic activity and meteorite impacts can inject large quantities of dust and gases into the atmosphere (ES.11 c). • Human activities have increased the carbon dioxide content of the atmosphere. Man-made chemicals have decreased the ozone concentration in the atmosphere (ES.11 c). • Climate change maintained deviation in at least two climatic variables. This natural process has been accelerated by human activities. Evidence for climate	

Enduring Understandings	Essential Knowledge and Practices
change includes: global temperature rise, warming oceans, shrinking ice sheets, glacial retreat, decreased snow cover, sea level rise, declining Arctic sea ice, extreme weather events, and ocean acidification (ES.11 c). • Legislation can promote change in human actions and reverse or stall the negative effects of their actions on the atmosphere. An example is evidenced through the policy that banned the use of chlorofluorocarbons (CFC) resulting in the reduction of ozone-layer depletion (ES.11 d).	

ES.12 The student will investigate and understand that Earth's weather and climate are the result of the interaction of the sun's energy with the atmosphere, oceans, and the land. Key ideas include

a) weather involves the reflection, absorption, storage, and redistribution of energy over short to medium time spans;
b) weather patterns can be predicted based on changes in current conditions;
c) extreme imbalances in energy distribution in the oceans, atmosphere, and the land may lead to severe weather conditions;
d) models based on current conditions are used to predict weather phenomena; and
e) changes in the atmosphere and the oceans due to human activity affect global climate.

Central Idea: Weather and climate are driven by the energy from the sun and the interaction of this energy with the atmosphere, oceans, and the land.

Vertical Alignment: The concept of weather, tools to measure weather conditions, and the ability to predict weather is focused on throughout elementary science. Students expand on the concept of weather to look at the causes of weather in sixth grade. These include the transfer of radiant energy, the impact of atmospheric conditions on weather, and that role of large bodies of water on weather and climate (6.4, 6.6, 6.7). In Earth Science, students study the interactions of the various systems as they influence weather.

Enduring Understandings	Essential Knowledge and Practices
All Earth's processes are the result of energy flowing and mass cycling within and among Earth's systems. Energy transfer between Earth's surface and the atmosphere creates the weather. • Earth's surface is much more efficiently heated by the sun than is the atmosphere. The amount of energy reaching any given point on Earth's surface is controlled by the angle of sunlight striking the surface and varies with the seasons (ES.12 a). • Winds are created by uneven heat distribution at Earth's surface and modified by the rotation of Earth. The Coriolis effect causes deflections of the atmosphere due to the rotation of Earth. Global wind patterns result from the uneven heating of Earth by the sun and are influenced by the Coriolis effect (ES.12 b). • Convection in the atmosphere is a major cause of weather. Convection is the major mechanism of energy transfer in the oceans, atmosphere, and Earth's interior (ES.12 b). • The conditions necessary for cloud formation are air at or below dew point and presence of condensation nuclei. Cloud droplets can join together to form precipitation (ES.12 b). • A tornado is a narrow, violent funnel-shaped column of spiral winds that extends downward from the cloud base toward Earth. A hurricane is a tropical cyclone (counterclockwise movement of air) characterized by sustained winds of 120 kilometers per hour (75 miles per hour) or greater (ES.12 c).	In order to meet this standard, it is expected that students will • research and construct a diagram that demonstrates the interaction of solar radiation, Earth's atmosphere, and energy transfer (conduction, convection, and radiation) (ES.12 a) • predict the direction of local winds and relate these to the presence of fronts and high- and/or low-pressure systems or other atmospheric phenomena (ES.12 b) • over a multi-day period, read and interpret data from a thermometer, a barometer, and a psychrometer; determine if there is a correlation between the data and observed weather phenomena (ES.12 b) • identify types and origins of air masses, fronts and the accompanying weather conditions (ES.12 b) • collect evidence for how the motions and complex interactions of air masses results in changes in weather conditions (ES.12 b) • plan and conduct an investigation to predict weather based on cloud type, temperature, jet stream location, relative humidity, and barometric pressure (ES.12 b) • read and interpret a weather map containing fronts, isobars, and isotherms and relate these factors to potential weather conditions occurring at specific locations (ES.12 b) • analyze the conditions that lead to severe weather events such as tornadoes and hurricanes. (ES.12 c) • describe the effect of satellite technology on weather prediction and storm tracking, including hurricanes, and

Enduring Understandings	Essential Knowledge and Practices
Models constructed based on patterns in atmospheric conditions are to predict weather. • Weather forecasting is the application of science and technology to predict the conditions of the atmosphere for a given location and time (ES.12 d). • Weather models take observational data (such as wind speed, wind direction, air temperature, pressure, and humidity) collected from many locations and sources across a region, and use mathematical equations that represent the physics of the atmosphere to fill in the gaps between measured points. Models then use these equations to predict what will happen in the future, including the development of storms and other weather events (ES.12 d). • Earth's climate is an example of how complex interactions among systems can result in relatively sudden and significant changes (ES.12 d). • Weather and climate are different. Both weather and climate are measurable and, to a certain extent, predictable. Weather describes day-to-day changes in atmospheric conditions. Climate describes the typical weather patterns for a given location over a period of many years. Instrumentation is used to collect weather and climate data (ES.12 e). • The four major factors affecting climate are latitude, elevation, proximity to bodies of water, and position relative to mountains. Earth's major climatic zones are the polar, temperate, and tropical zones. Areas near the equator receive	evaluate the costs and benefits in terms of lives and property saved; predict the impact on storm preparedness if there were no weather satellites (ES.12 d) • describe human and natural factors that have led to the rise in global temperature over the past century (ES.12 e) • analyze geoscience data and the results of global climate models to make an evidence-based forecast of the current rate of global and regional climate change and associated future effects on Earth systems (ES.12 e).

Enduring Understandings	Essential Knowledge and Practices
more of the sun’s energy per unit area than areas nearer the poles (ES.12 e).	