Science Standards of Learning

for Virginia Public Schools

Board of Education
Commonwealth of Virginia

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Notice to Reader

Preface

In 1995, the Virginia Board of Education published Standards of Learning in English, mathematics, science, and history and social science for kindergarten through grade 12. Subsequently, Standards of Learning were developed for all academic content areas. The Standards of Learning provide a framework for instructional programs designed to raise the academic achievement of all students in Virginia and to prepare students for post-secondary success. School divisions and teachers incorporate the standards in local curriculum and classroom instruction.

The Standards of Learning set reasonable targets and expectations for what teachers must teach and students must learn. The standards are not intended to encompass the entire curriculum for a given grade level or course or to prescribe how the content should be taught; the standards are to be incorporated into a broader, locally designed curriculum. Teachers are encouraged to go beyond the standards and select instructional strategies and assessment methods appropriate for their students.

The Standards of Learning were developed through a series of public hearings and the efforts of parents, teachers, representatives from higher education, science education organizations, and business and industry leaders. The standards set clear and concise academic expectations for young people. Parents are encouraged to work with their children to help them achieve these academic standards.

Introduction

The *Science Standards of Learning* for Virginia Public Schools identify academic content for essential components of the science curriculum at different grade levels. The content of the standards, in conjunction with effective instruction, provide a platform for creating scientifically literate students. The *Science Standards of Learning* reflect a vertical progression of content and practices. The Standards of Learning contain content strands or topics that progress in complexity as they are studied at various grade levels in grades K-5 and are represented indirectly throughout the middle and high school courses. These strands are

- Scientific and Engineering Practices
- Force, Motion, and Energy
- Matter
- Living Systems and Processes
- Earth and Space Systems
- Earth Resources

Six critical components for achieving science literacy are 1) Goals; 2) Investigate and Understand; 3) Nature of Science; 4) Science and Engineering Practices; 5) K-12 Safety; and 6) Instructional Technology. These six components support the Profile of a Virginia Graduate and an integrated instructional approach that incorporates science, technology, engineering, and mathematics (STEM). It is imperative to science instruction that the local curriculum consider and address how these components are incorporated in the design of the K-12 science program.

Goals

The *Science Standards of Learning* for Virginia Public Schools serve as a framework for educators to meet science education goals and support students' investigation of the natural world. The goals of science instruction include

- Use scientific processes to safely investigate the natural world;
- Develop the scientific knowledge, skills, and attributes to be successful in college, explore science-related careers and interests, and be work-force ready ;
- Develop scientific dispositions and habits of mind (collaboration, curiosity, creativity, demand for verification, open-mindedness, respect for logical and rational thinking, objectivity, learning from mistakes, patience, and persistence);
- Possess significant knowledge of science to be informed consumers with the ability to communicate and use science in their everyday lives and engage in public discussions;
- Make informed decisions regarding contemporary civic, environmental, and economic issues;
- Apply knowledge of mathematics and science in an authentic way using the engineering design process to solve societal problems; and
- Develop an understanding of the interrelationship of science with technology, engineering and mathematics (STEM).

Investigate and Understand

Many of the standards in the *Science Standards of Learning* begin with the phrase "Students will investigate and understand." This phrase communicates the wide range of science knowledge, skills, and practices required to effectively investigate and understand the natural world. "Investigate" refers to scientific methodology and implies systematic use of the following inquiry and engineering skills:

- 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
- Obtaining, evaluating, and communicating information

"Understand" refers to the application of scientific knowledge including the ability to:

- apply understanding of key science concepts and the nature of science;
- use important information, key definitions, terminology, and facts to make judgments about information in terms of its accuracy, precision, consistency, or effectiveness;
- apply information and principles to new problems or situations, recognizing what information is required for a particular situation, using the information to explain new phenomena, and determining when there are exceptions;
- explain the information in one's own words, comprehend how the information is related to other key facts, and suggest additional interpretations of its meaning or importance;
- think critically, problem-solve, and make decisions;
- analyze the underlying details of important facts and principles, recognizing the key relations and patterns that are not always readily visible; and
- arrange and combine important facts, principles, and other information to produce a new idea, plan, procedure, or product to solve problems.

Therefore, the use of "investigate and understand" allows each content standard to become the basis for a broad range of teaching objectives, which the school division will develop and refine to meet the intent of the *Science Standards of Learning*.

Nature of Science

Science is not a mere accumulation of facts; instead, it is a discipline with common practices for understanding the natural world. The nature of science describes these common practices employed by scientists and it reflects the intrinsic values and assumptions of scientific knowledge. The nature of science explains the functioning of science, what science is, how it develops and builds the knowledge it generates, and the methodology used to disseminate and validate knowledge.

Regardless of the career that a student chooses to pursue, all students should be science literate with an understanding of the nature of science and the scientific knowledge and skills necessary to make informed decisions.

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 competences with techniques at the heart of each discipline.

K-12 Safety

In implementing the *Science Standards of Learning*, teachers must be certain that students know how to follow safety guidelines, demonstrate appropriate laboratory safety techniques, and use equipment safely while working individually and in groups.

Safety must be given the highest priority in implementing the K-12 instructional program for science. Correct and safe techniques, as well as wise selection of experiments, resources, materials, and field experiences appropriate to age levels, must be carefully considered with regard to the safety precautions for every instructional activity. Safe science classrooms require thorough planning, careful management, and constant monitoring of student activities. Class enrollment should not exceed the designed capacity of the room.

Teachers must be knowledgeable of the properties, use, and proper disposal of all chemicals that may be judged as hazardous before their use in an instructional activity. Such information is referenced through Safety Data Sheets (SDS), which conform to the requirements of the Globally Harmonized System of Classification and Labeling of Chemicals (GHS), effective May 2012. The identified precautions involving the use of goggles, gloves, aprons, and fume hoods must be followed as prescribed.

The following sources offer further guidance on science safety:

- Occupational Safety and Health Administration;
- International Science and Engineering Fair rules;
- Virginia Department of Education (VDOE) Science Safety Handbook on the VDOE Science Instruction webpage;
- American Chemical Society (ACS) resources: *Safety in the Elementary Science Classroom, Chemical Safety for Teachers and their Supervisors*, and *Guidelines for Chemical Laboratory Safety* on the ACS webpage; and
- public health departments' and school divisions' protocols and chemical hygiene plans.

Instructional Technology

The primary purpose of the use of instructional technology is to support effective teaching and learning. A secondary purpose is to aid in preparing students for life after their K-12 education by ensuring that they are skillful in using current technology tools and in learning how to use new tools that may benefit their personal and professional lives. As such, the use of current and emerging technology is essential to the K-12 science instructional program.

Effective use of instructional technology in the science classroom requires that technology is integrated throughout the curriculum, is seamless in its application, and includes instrumentation oriented toward the teaching and learning of science concepts, skills, and processes. In addition to traditional instruments of science, such as microscopes, lab ware, and data-collecting apparatus, the technology used should also include computers, robotics, video-microscopes, graphing calculators, probeware, geospatial technologies, online communication, software, appropriate hardware, and other applicable emerging technologies.

Profile of a Virginia Graduate

The *2018 Science Standards of Learning* support the Profile of a Virginia Graduate through the development and use of communication, collaboration, critical thinking, and creative thinking skills and the applications of civic responsibility in the understanding and applications of science.

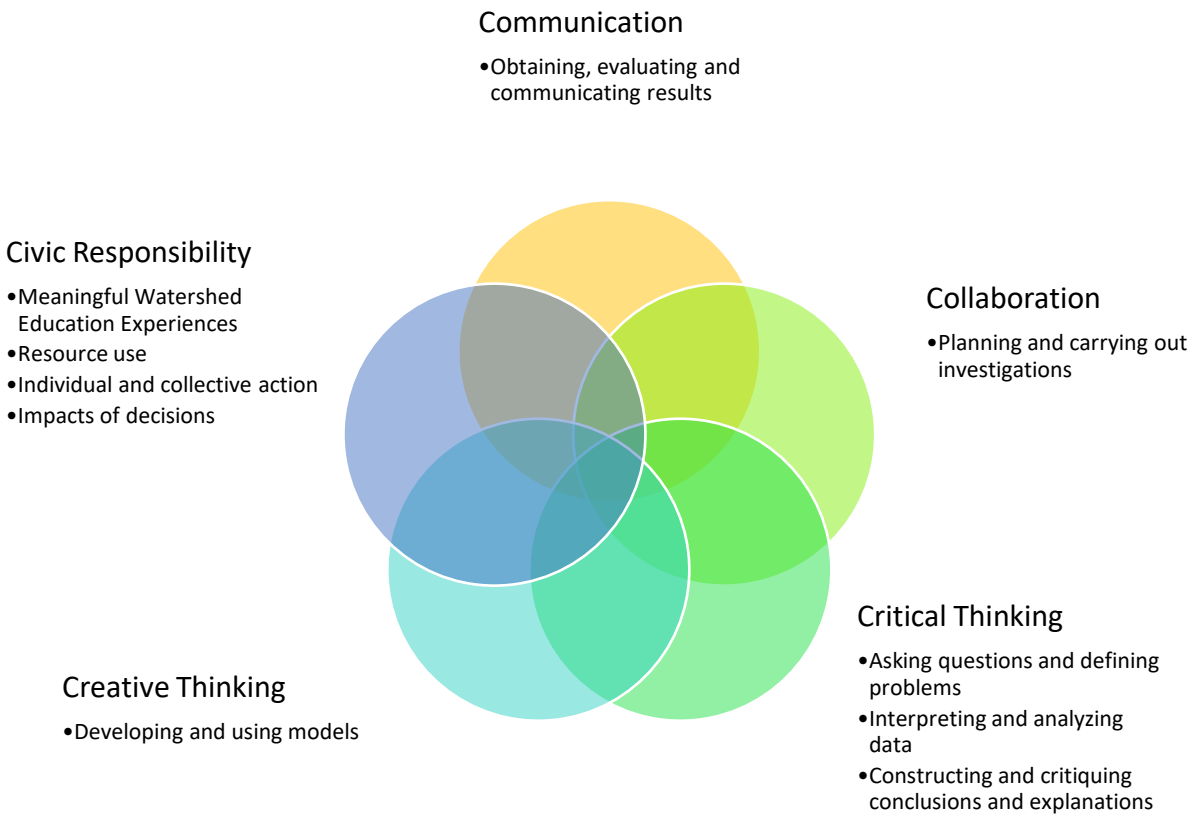

Figure 1: Visual representation of the science skills and processes aligned to the Profile of a Virginia Graduate

Kindergarten

Using my senses to understand my world

In science, kindergarten students use their senses to make observations of the characteristics and interactions of objects in their world. Students study the characteristics of water and the basic needs of living things. They also study the relationship between the sun and Earth through shadows and weather. They determine how their actions can change the motion of objects and learn how they can make a difference in their world. Throughout the elementary years, students will develop scientific skills, supported by mathematics and computational thinking, as they learn science content. In kindergarten, students will develop skills in posing simple questions, conducting simple investigations, observing, classifying, and communicating information about the natural world.

Scientific and Engineering Practices

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

a) asking questions and defining problems
   - ask questions based on observations
   - identify a problem based on need
   - make predictions based on observations

b) planning and carrying out investigations
   - make observations to collect data
   - identify characteristics and properties of objects through observations
   - measure the relative length and weight of common objects
   - record information from investigations

c) interpreting, analyzing, and evaluating data
   - describe patterns
   - classify and/or sequence objects based on a single physical characteristic or property
   - organize and represent data
   - read and interpret data in object graphs, picture graphs, and tables

d) constructing and critiquing conclusions and explanations
   - make simple conclusions based on data or observations

e) developing and using models
   - distinguish between a model and an actual object

f) obtaining, evaluating, and communicating information
   - communicate comparative measures (e.g., heavier, lighter, longer, shorter, more, less, hotter, colder)
   - communicate observations using pictures, drawings, and/or speech

Force, Motion, and Energy

K.2 The student will investigate and understand that pushes and pulls affect the motion of objects. Key ideas include
a) pushes and pulls can cause an object to move;
b) pushes and pulls can change the direction of an object; and
c) changes in motion are related to the strength of the push or pull.

Matter

K.3 The student will investigate and understand that physical properties of an object can be described. Properties include
a) colors;
b) shapes and forms;
c) textures and feel; and
d) relative sizes and weights of objects.

K.4 The student will investigate and understand that water is important in our daily lives and has properties. Key ideas include
a) water has many uses;
b) water can be found in many places;
c) water occurs in different phases; and
d) water flows downhill.

Living Systems and Processes

K.5 The students will investigate and understand that senses allow humans to seek, find, take in, and react or respond to different information. Key ideas include
a) the five basic senses correspond to specific human body structures; and
b) senses are used in our daily lives.

K.6 The student will investigate and understand that there are differences between living organisms and nonliving objects. Key ideas include
a) all things can be classified as living or nonliving; and
b) living organisms have certain characteristics that distinguish them from nonliving objects.

K.7 The student will investigate and understand that plants and animals have basic needs and life processes. Key ideas include
a) living things need adequate food, water, shelter, air, and space to survive;
b) plants and animals have life cycles; and
c) offspring of plants and animals are similar but not identical to their parents or to one another.

Earth and Space Systems

K.8 The student will investigate and understand that light influences temperature on Earth's surfaces and can cause shadows. Key ideas include
a) the sun provides light and warms Earth's surface;
b) shadows can be produced when sunlight or artificial light is blocked by an object; and
c) objects in shadows and objects in sunlight have different temperatures.

K.9 The student will investigate and understand that there are patterns in nature. Key patterns include
a) daily weather;
b) seasonal changes; and
c) day and night.

K.10 The student will investigate and understand that change occurs over time. Key ideas include
a) natural and human-made things change over time;
b) living and nonliving things change over time;
c) changes can be observed and measured; and
d) changes may be fast or slow.

Earth Resources

K.11 The student will investigate and understand that humans use resources. Key ideas include
a) some materials and objects can be used over and over again;
b) materials can be recycled; and
c) choices we make impact the air, water, land and living things.

Grade One

How I interact with my world

In first-grade science, students become aware of factors that affect their daily lives. Students continue to learn about the basic needs of all living things and that living things respond to factors in their environment, including weather and the change of season. They continue the examination of matter by observing physical properties and how materials interact with light. Throughout the elementary years, students will develop scientific skills, supported by mathematics and computational thinking, as they learn science content. In first grade, students will develop skills in posing simple questions, conducting simple investigations, observing, classifying, and communicating information about the natural world. Students are introduced to the engineering design process.

Scientific and Engineering Practices

1.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
- ask questions and make predictions based on observations
- identify a simple problem that can be solved through the development of a new tool or improved object

b) planning and carrying out investigations
- with guidance, conduct investigations to produce data
- identify characteristics and properties of objects by observations
- use tools to measure relative length, weight, volume, and temperature of common objects

c) interpreting, analyzing, and evaluating data
- use and share pictures, drawings, and/or writings of observations
- describe patterns and relationships
- classify and arrange objects based on a single physical characteristic or property
- organize and represent various forms of data using tables, picture graphs, and object graphs
- read and interpret data displayed in tables, picture graphs, and object graphs, using the vocabulary *more, less, fewer, greater than, less than, and equal to*

d) constructing and critiquing conclusions and explanations
- make simple conclusions based on data or observations
- recognize unusual or unexpected results

e) developing and using models
- use physical models to demonstrate simple phenomena and natural processes

f) obtaining, evaluating, and communicating information
- communicate observations and data using simple graphs, pictures, drawings, numbers, speech and/or writing

Force, Motion, and Energy

1.2 The student will investigate and understand that objects can move in different ways. Key ideas include
   a) objects may have straight, circular, spinning, and back-and-forth motions; and
   b) objects may vibrate and produce sound.

Matter

1.3 The student will investigate and understand that objects are made from materials that can be described by their physical properties. Key ideas include
   a) objects are made of one or more materials with different physical properties and can be used for a variety of purposes;
   b) when a material is changed in size most physical properties remain the same; and
   c) the type and amount of material determine how much light can pass through an object.

Living Systems and Processes

1.4 The student will investigate and understand that plants have basic life needs and functional parts that allow them to survive. Key ideas include
   a) plants need nutrients, air, water, light, and a place to grow;
   b) structures of plants perform specific functions; and
   c) plants can be classified based on a variety of characteristics.

1.5 The student will investigate and understand that animals, including humans, have basic life needs that allow them to survive. Key ideas include
   a) animals need air, food, water, shelter, and space (habitat);
   b) animals have different physical characteristics that perform specific functions; and
   c) animals can be classified based on a variety of characteristics.

Earth and Space Systems

1.6 The student will investigate and understand that there is a relationship between the sun and Earth. Key ideas include
   a) the sun is the source of energy and light that warms the Earth's land, air, and water; and
   b) the sun's relative position changes in the Earth's sky throughout the day.

1.7 The student will investigate and understand that there are weather and seasonal changes. Key ideas include
   a) changes in temperature, light, and precipitation occur over time;
   b) there are relationships between daily weather and the season; and
   c) changes in temperature, light, and precipitation affect plants and animals, including humans.

Earth Resources

1.8 The student will investigate and understand that natural resources can be used responsibly. Key ideas include
   a) most natural resources are limited;
   b) human actions can affect the availability of natural resources; and
   c) reducing, reusing, and recycling are ways to conserve natural resources.

Grade Two

Change occurs all around us

Science in second grade builds on previous understandings of forces, water, weather, and plants and animals, and students explore these concepts through the lens of change. They examine how water changes phase, how visible and invisible forces change motion, how plants and animals change through their life cycles, and how weather changes the Earth. Students also examine how change occurs over a short or long period of time. Throughout the elementary years, students will develop scientific skills, supported by mathematics and computational thinking, as they learn science content. In second grade, students will develop skills in posing simple questions, planning and conducting simple investigations, observing, classifying, and communicating information about the natural world. Students engage in more aspects of the engineering design process at this level.

Scientific and Engineering Practices

2.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask questions that can be investigated
   - make predictions based on observations and prior experiences
   - identify a simple problem that can be solved through the development of a new tool or improved object

b) planning and carrying out investigations
   - with guidance, plan and conduct simple investigations to produce data
   - use appropriate tools to measure length, weight, and temperature of common objects using U.S. Customary units
   - measure time intervals using proper tools

c) interpreting, analyzing, and evaluating data
   - organize and represent data in pictographs and bar graphs
   - read and interpret data represented in pictographs and bar graphs

d) constructing and critiquing conclusions and explanations
   - make simple conclusions based on data or observations
   - distinguish between opinion and evidence
   - recognize unusual or unexpected results

e) developing and using models
   - use models to demonstrate simple phenomena and natural processes

f) obtaining, evaluating, and communicating information
   - communicate observations and data using simple graphs, drawings, numbers, speech, and/or writing

Force, Motion, and Energy

2.2 The student will investigate and understand that different types of forces may cause an object's motion to change. Key ideas include
- a) forces from direct contact can cause an object to move;
- b) some forces, including gravity and magnetism, can cause objects to move from a distance; and
- c) forces have applications in our lives.

Matter

2.3 The student will investigate and understand that matter can exist in different phases. Key ideas include
- a) matter has mass and takes up space;
- b) solids, liquids, and gases have different characteristics; and
- c) heating and cooling can change the phases of matter.

Living Systems and Processes

2.4 The student will investigate and understand that plants and animals undergo a series of orderly changes as they grow and develop. Key ideas include
- a) animals have life cycles; and
- b) plants have life cycles.

2.5 The student will investigate and understand that living things are part of a system. Key ideas include
- a) plants and animals are interdependent with their living and nonliving surroundings;
- b) an animal's habitat provides all of its basic needs; and
- c) habitats change over time due to many influences.

Earth and Space Systems

2.6 The student will investigate and understand that there are different types of weather on Earth. Key ideas include
- a) different types of weather have specific characteristics;
- b) measuring, recording, and interpreting weather data allows for identification of weather patterns; and
- c) tracking weather allows us to prepare for the weather and storms.

2.7 The student will investigate and understand that weather patterns and seasonal changes affect plants, animals, and their surroundings. Key ideas include
- a) weather and seasonal changes affect the growth and behavior of living things;
- b) wind and weather can change the land; and
- c) changes can happen quickly or slowly over time.

Earth Resources

2.8 The student will investigate and understand that plants are important natural resources. Key ideas include

a) the availability of plant products affects the development of a geographic area;
b) plants provide oxygen, homes, and food for many animals; and
c) plants can help reduce the impact of wind and water.

Grade Three

Interactions in our world

The focus of science in third grade is interactions in our world. Students continue to study forces and matter by learning about simple machines and by examining the interactions of materials in water. They also look at how plants and animals, including humans, are constantly interacting with the living and nonliving aspects of the environment. This includes examining how adaptations satisfy life needs of plants and the importance of water, soil, and the sun in the survival of plants and animals. Throughout the elementary years, students will develop scientific skills, supported by mathematics and computational thinking, as they learn science content. In third grade, students will develop more sophisticated skills in posing questions and predicting outcomes, planning and conducting simple investigations, collecting and analyzing data, constructing explanations, and communicating information about the natural world. Students begin to use the engineering design process to apply their scientific knowledge to solve problems.

Scientific and Engineering Practices

3.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
- ask questions that can be investigated and predict reasonable outcomes
- ask questions about what would happen if a variable is changed
- define a simple design problem that can be solved through the development of an object, tool, process, or system

b) planning and carrying out investigations
- with guidance, plan and conduct investigations
- use appropriate methods and/or tools for collecting data
- estimate length, mass, volume, and temperature
- measure length, mass, volume, and temperature in metric and U.S. Customary units using proper tools
- measure elapsed time
- use tools and/or materials to design and/or build a device that solves a specific problem

c) interpreting, analyzing, and evaluating data
- organize and represent data in pictographs or bar graphs
- read, interpret, and analyze data represented in pictographs and bar graphs
- analyze data from tests of an object or tool to determine if it works as intended

d) constructing and critiquing conclusions and explanations
- use evidence (measurements, observations, patterns) to construct or support an explanation
- generate and/or compare multiple solutions to a problem
- describe how scientific ideas apply to design solutions

e) developing and using models

- use models to demonstrate simple phenomena and natural processes
- develop a model (e.g., diagram or simple physical prototype) to illustrate a proposed object, tool, or process

f) obtaining, evaluating, and communicating information
- read and comprehend reading-level appropriate texts and/or other reliable media
- communicate scientific information, design ideas, and/or solutions with others

Force, Motion, and Energy

3.2 The student will investigate and understand that the direction and size of force affects the motion of an object. Key ideas include
a) multiple forces may act on an object;
b) the net force on an object determines how an object moves;
c) simple machines increase or change the direction of a force; and
d) simple and compound machines have many applications.

Matter

3.3 The student will investigate and understand how materials interact with water. Key ideas include
a) solids and liquids mix with water in different ways; and
b) many solids dissolve more easily in hot water than in cold water.

Living Systems and Processes

3.4 The student will investigate and understand that adaptations allow organisms to satisfy life needs and respond to the environment. Key ideas include
a) populations may adapt over time;
b) adaptations may be behavioral or physical; and
c) fossils provide evidence about the types of organisms that lived long ago as well as the nature of their environments.

3.5 The student will investigate and understand that aquatic and terrestrial ecosystems support a diversity of organisms. Key ideas include
a) ecosystems are made of living and nonliving components of the environment; and
b) relationships exist among organisms in an ecosystem.

Earth and Space Systems

3.6 The student will investigate and understand that soil is important in ecosystems. Key ideas include
a) soil, with its different components, is important to organisms; and
b) soil provides support and nutrients necessary for plant growth.

3.7 The student will investigate and understand that there is a water cycle and water is important to life on Earth. Key ideas include

a) there are many reservoirs of water on Earth;
b) the energy from the sun drives the water cycle; and
c) the water cycle involves specific processes.

Earth Resources

3.8 The student will investigate and understand that natural events and humans influence ecosystems. Key ideas include

a) human activity affects the quality of air, water, and habitats;
b) water is limited and needs to be conserved;
c) fire, flood, disease, and erosion affect ecosystems; and
d) soil is a natural resource and should be conserved.

Grade Four

Our place in the solar system

Our solar system is a grand place, and in fourth-grade science, students learn where we fit in this solar system. Starting with the solar system, and then moving to the planet Earth, the Commonwealth of Virginia, and finally their specific ecosystems, students examine how features of plants and animals support life. They also explore how living things interact with both living and nonliving components in their ecosystems. Throughout the elementary years, students will develop scientific skills, supported by mathematics and computational thinking, as they learn science content. In fourth grade, students will continue to develop skills in posing questions and predicting outcomes, planning and conducting simple investigations, collecting and analyzing data, constructing explanations, and communicating information about the natural world. Students continue to use the engineering design process to apply their scientific knowledge to solve problems.

Scientific and Engineering Practices

4.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
- identify scientific and non-scientific questions
- develop hypotheses as cause-and-effect relations
- define a simple design problem that can be solved through the development of an object, tool, process, or system

b) planning and carrying out investigations
- identify variables when planning an investigation
- collaboratively plan and conduct investigations
- use tools and/or materials to design and/or build a device that solves a specific problem
- take metric measurements using appropriate tools
- measure elapsed time

c) interpreting, analyzing, and evaluating data
- organize and represent data in bar graphs and line graphs
- interpret and analyze data represented in bar graphs and line graphs
- compare two different representations of the same data (e.g., a set of data displayed on a chart and a graph)
- analyze data from tests of an object or tool to determine whether it works as intended

d) constructing and critiquing conclusions and explanations
- use evidence (i.e., measurements, observations, patterns) to construct or support explanations and to make inferences

e) developing and using models
- develop and/or use models to explain natural phenomena
- identify limitations of models

f) obtaining, evaluating, and communicating information
   - read and comprehend reading-level-appropriate texts and/or other reliable media
   - communicate scientific information, design ideas, and/or solutions with others

Living Systems and Processes

4.2 The student will investigate and understand that plants and animals have structures that distinguish them from one another and play vital roles in their ability to survive. Key ideas include
   a) the survival of plants and animals depends on photosynthesis;
   b) plants and animals have different structures and processes for obtaining energy; and
   c) plants and animals have different structures and processes for creating offspring.

4.3 The student will investigate and understand that organisms, including humans, interact with one another and with the nonliving components in the ecosystem. Key ideas include
   a) interrelationships exist in populations, communities, and ecosystems;
   b) food webs show the flow of energy within an ecosystem;
   c) changes in an organism's niche and habitat may occur at various stages in its life cycle; and
   d) classification can be used to identify organisms.

Earth and Space Systems

4.4 The student will investigate and understand that weather conditions and phenomena affect ecosystems and can be predicted. Key ideas include
   a) weather measurements create a record that can be used to make weather predictions;
   b) common and extreme weather events affect ecosystems; and
   c) long term seasonal weather trends determine the climate of a region.

4.5 The student will investigate and understand that the planets have characteristics and a specific place in the solar system. Key ideas include
   a) planets rotate on their axes and revolve around the sun;
   b) planets have characteristics and a specific order in the solar system; and
   c) the sizes of the sun and planets can be compared to one another.

4.6 The student will investigate and understand that there are relationships among Earth, the moon, and the sun. Key relationships include
   a) the motions of Earth, the moon, and the sun;
   b) the causes for Earth's seasons;
   c) the causes for the four major phases of the moon and the relationship to the tide cycles; and

d) the relative size, position, age and makeup of Earth, the moon, and the sun.

4.7 The student will investigate and understand that the ocean environment has characteristics. Key characteristics include
a) geology of the ocean floor;
b) physical properties and movement of ocean water; and
c) interaction of organisms in the ocean.

Earth Resources

4.8 The student will investigate and understand that Virginia has important natural resources. Key resources include
a) watersheds and water;
b) plants and animals;
c) minerals, rocks, and ores; and
d) forests, soil, and land.

Grade Five

Transforming matter and energy

Grade five science delves more deeply into foundational concepts in physical science as students begin to make connections between energy and matter. Students explore how energy is transformed, and learn about electricity, sound, and light. They also learn about the composition of matter and explore how energy can change phases of matter. Students apply an understanding of force, matter, and energy when they explore how the Earth's surface changes. Students continue to develop scientific skills and processes as they pose questions and predict outcomes, plan and conduct investigations, collect and analyze data, construct explanations, and communicate information about the natural world. Mathematics and computational thinking gain importance as students advance in their scientific thinking. Students continue to use the engineering design process to apply their scientific knowledge to solve problems.

Scientific and Engineering Practices

5.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask testable questions based on observations and predict reasonable outcomes based on patterns
   - develop hypotheses as cause-and-effect relationship
   - define design problems that can be solved through the development of an object, tool, process, or system

b) planning and carrying out investigations
   - collaboratively plan and conduct investigations to produce data
   - identify independent variable, dependent variables, and constants
   - determine data that should be collected to answer a testable question
   - take metric measurements using appropriate tools
   - use tools and/or materials to design and/or build a device that solves a specific problem

c) interpreting, analyzing, and evaluating data
   - represent and analyze data using tables and graphs
   - organize simple data sets to reveal patterns that suggest relationships
   - compare and contrast data collected by different groups and discuss similarities and differences in their findings
   - use data to evaluate and refine design solutions

d) constructing and critiquing conclusions and explanations
   - construct and/or support arguments with evidence, data, and/or a model
   - describe how scientific ideas apply to design solutions
   - generate and compare multiple solutions to problems based on how well they meet the criteria and constraints

e) developing and using models

- develop models using an analogy, example, or abstract representation to describe a scientific principle or design solution
- identify limitations of models

f) obtaining, evaluating, and communicating information
- read and comprehend reading-level-appropriate texts and/or other reliable media
- communicate scientific information, design ideas, and/or solutions with others

Force, Motion, and Energy

5.2 The student will investigate and understand that energy can take many forms. Key ideas include
a) energy is the ability to do work or to cause change;
b) there are many different forms of energy;
c) energy can be transformed; and
d) energy is conserved.

5.3 The student will investigate and understand that there is a relationship between force and energy of moving objects. Key ideas include
a) moving objects have kinetic energy;
b) motion is described by an object's direction and speed;
c) changes in motion are related to net force and mass;
d) when objects collide, the contact forces transfer energy and can change objects' motion; and
e) friction is a force that opposes motion.

5.4 The student will investigate and understand that electricity is transmitted and used in daily life. Key ideas include
a) electricity flows easily through conductors but not insulators;
b) electricity flows through closed circuits;
c) static electricity can be generated by rubbing certain materials together;
d) electrical energy can be transformed into radiant, mechanical, and thermal energy; and
e) a current flowing through a wire creates a magnetic field.

5.5 The student will investigate and understand that sound can be produced and transmitted. Key ideas include
a) sound is produced when an object or substance vibrates;
b) sound is the transfer of energy;
c) different media transmit sound differently; and
d) sound waves have many uses and applications.

5.6 The student will investigate and understand that visible light has certain characteristics and behaves in predictable ways. Key ideas include
   a) visible light is radiant energy that moves in transverse waves;
   b) the visible spectrum includes light with different wavelengths;
   c) matter influences the path of light; and
   d) radiant energy can be transformed into thermal, mechanical, and electrical energy.

Matter

5.7 The student will investigate and understand that matter has properties and interactions. Key ideas include
   a) matter is composed of atoms;
   b) substances can be mixed together without changes in their physical properties; and
   c) energy has an effect on the phases of matter.

Earth and Space Systems

5.8 The student will investigate and understand that Earth constantly changes. Key ideas include
   a) Earth's internal energy causes movement of material within the Earth;
   b) plate tectonics describe movement of the crust;
   c) the rock cycle models the transformation of rocks;
   d) processes such as weathering, erosion, and deposition change the surface of the Earth; and
   e) fossils and geologic patterns provide evidence of Earth's change.

Earth Resources

5.9 The student will investigate and understand that the conservation of energy resources is important. Key ideas include
   a) some sources of energy are considered renewable and others are not;
   b) individuals and communities have means of conserving both energy and matter; and
   c) advances in technology improve the ability to transfer and transform energy.

Grade Six

Our world; our responsibility

In sixth grade, students are transitioning from elementary to middle school. The science standards support that transition as students examine more abstract concepts, providing a foundation in the disciplines of science. They explore the characteristics of their world, from the Earth's placement in the solar system to the interactions of water, energy, air, and ecosystems on the Earth. As students more closely examine the use of resources, they also consider how their actions and choices affect future habitability of Earth. Students continue to develop scientific skills and processes as they pose questions and predict outcomes, plan and conduct investigations, collect and analyze data, construct explanations, and communicate information about the natural world. Mathematics and computational thinking gain importance as students advance in their scientific thinking. Students continue to use the engineering design process to apply their scientific knowledge to solve problems.

6.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask questions to determine relationships between independent and dependent variables
   - develop hypotheses and identify independent and dependent variables
   - offer simple solutions to design problems

b) planning and carrying out investigations
   - independently and collaboratively plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate, and include the safe use of chemicals and equipment
   - evaluate the accuracy of various methods for collecting data
   - take metric measurements using appropriate tools
   - use tools and materials to design and/or build a device to solve a specific problem

c) interpreting, analyzing, and evaluating data
   - organize data sets to reveal patterns that suggest relationships
   - construct, analyze, and interpret graphical displays of data
   - compare and contrast data collected by different groups and discuss similarities and differences in findings
   - use data to evaluate and refine design solutions

d) constructing and critiquing conclusions and explanations
   - construct explanations that includes qualitative or quantitative relationships between variables
   - construct scientific explanations based on valid and reliable evidence obtained from sources (including the students' own investigations)
   - generate and compare multiple solutions to problems based on how well they meet the criteria and constraints

e) developing and using models
   - use scale models to represent and estimate distance
   - use, develop, and revise models to predict and explain phenomena
   - evaluate limitations of models

f) obtaining, evaluating, and communicating information
   - read scientific texts, including those adapted for classroom use, to obtain scientific and/or technical information
   - gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication
   - construct, use, and/or present an argument supported by empirical evidence and scientific reasoning

6.2 The student will investigate and understand that the solar system is organized and the various bodies in the solar system interact. Key ideas include

a) matter is distributed throughout the solar system;
b) planets have different sizes and orbit at different distances from the sun;
c) gravity contributes to orbital motion; and
d) the understanding of the solar system has developed over time.

6.3 The student will investigate and understand that there is a relationship between the sun, Earth, and the moon. Key ideas include

a) Earth has unique properties;
b) the rotation of Earth in relationship to the sun causes day and night;
c) the movement of Earth and the moon in relationship to the sun causes phases of the moon;
d) Earth's tilt as it revolves around the sun causes the seasons; and
e) the relationship between Earth and the moon is the primary cause of tides.

6.4 The student will investigate and understand that there are basic sources of energy and that energy can be transformed. Key ideas include

a) the sun is important in the formation of most energy sources on Earth;
b) Earth's energy budget relates to living systems and Earth's processes;
c) radiation, conduction, and convection distribute energy; and
d) energy transformations are important in energy usage.

6.5 The student will investigate and understand that all matter is composed of atoms. Key ideas include

a) atoms consist of particles, including electrons, protons, and neutrons;
b) atoms of a particular element are similar but differ from atoms of other elements;
c) elements may be represented by chemical symbols;
d) two or more atoms interact to form new substances, which are held together by electrical forces (bonds);
e) compounds may be represented by chemical formulas;
f) chemical equations can be used to model chemical changes; and

g) a few elements comprise the largest portion of the solid Earth, living matter, the oceans, and the atmosphere.

6.6 The student will investigate and understand that water has unique physical properties and has a role in the natural and human-made environment. Key ideas include

a) water is referred to as the universal solvent;
b) water has specific properties;
c) thermal energy has a role in phase changes;
d) water has a role in weathering;
e) large bodies of water moderate climate; and
f) water is important for agriculture, power generation, and public health.

6.7 The student will investigate and understand that air has properties and that Earth's atmosphere has structure and is dynamic. Key ideas include

a) air is a mixture of gaseous elements and compounds;
b) the atmosphere has physical characteristics;
c) properties of the atmosphere change with altitude;
d) there is a relationship between air movement, thermal energy, and weather conditions;
e) atmospheric measures are used to predict weather conditions; and
f) weather maps give basic information about fronts, systems, and weather measurements.

6.8 The student will investigate and understand that land and water have roles in watershed systems. Key ideas include

a) a watershed is composed of the land that drains into a body of water;
b) Virginia is composed of multiple watershed systems which have specific features;
c) the Chesapeake Bay is an estuary that has many important functions; and
d) natural processes, human activities, and biotic and abiotic factors influence the health of a watershed system.

6.9 The student will investigate and understand that humans impact the environment and individuals can influence public policy decisions related to energy and the environment. Key ideas include

a) natural resources are important to protect and maintain;
b) renewable and nonrenewable resources can be managed;
c) major health and safety issues are associated with air and water quality;
d) major health and safety issues are related to different forms of energy;
e) preventive measures can protect land-use and reduce environmental hazards; and
f) there are cost/benefit tradeoffs in conservation policies.

Life Science

The Life Science standards emphasize a more complex understanding of change, cycles, patterns, and relationships in the living world. Students build on basic principles related to these concepts by exploring the cellular organization and the classification of organisms; the dynamic relationships among organisms, populations, communities, and ecosystems; and change as a result of the transmission of genetic information from generation to generation. Students build on scientific investigation skills by independently identifying questions and planning investigations. Students evaluate the usefulness and limits of models and support their conclusions using evidence. Mathematics, computational thinking, and experience in the engineering design process gain importance as students advance in their scientific thinking.

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

a) asking questions and defining problems
   - ask questions and develop hypotheses to determine relationships between independent and dependent variables
   - offer simple solutions to design problems

b) planning and carrying out investigations
   - independently and collaboratively plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate and include the safe use of chemicals and equipment
   - evaluate the accuracy of various methods for collecting data
   - take metric measurements using appropriate tools and technologies including the use of microscopes

c) interpreting, analyzing, and evaluating data
   - identify, interpret, and evaluate patterns in data
   - construct, analyze, and interpret graphical displays of data
   - compare and contrast data collected by different groups and discuss similarities and differences in their findings
   - consider limitations of data analysis and/or seek to improve precision and accuracy of data
   - use data to evaluate and refine design solutions

d) constructing and critiquing conclusions and explanations
   - construct explanations that include qualitative or quantitative relationships between variables
   - construct scientific explanations based on valid and reliable evidence obtained from sources (including the students' own investigations)
   - differentiate between a scientific hypothesis and theory

e) developing and using models
   - construct and use models and simulations to illustrate, predict, and/or explain observable and unobservable phenomena, life processes, or mechanisms
   - evaluate limitations of models

f) obtaining, evaluating, and communicating information
   - read scientific texts, including those adapted for classroom use, to obtain scientific and/or technical information
   - gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication
   - construct, use, and/or present an argument supported by empirical evidence and scientific reasoning

LS.2 The student will investigate and understand that all living things are composed of one or more cells that support life processes, as described by the cell theory. Key ideas include
a) the development of the cell theory demonstrates the nature of science;
b) cell structure and organelles support life processes;
c) similarities and differences between plant and animal cells determine how they support life processes;
d) cell division is the mechanism for growth and reproduction; and
e) cellular transport (osmosis and diffusion) is important for life processes.

LS.3 The student will investigate and understand that there are levels of structural organization in living things. Key ideas include
a) patterns of cellular organization support life processes;
b) unicellular and multicellular organisms have comparative structures; and
c) similar characteristics determine the classification of organisms.

LS.4 The student will investigate and understand that there are chemical processes of energy transfer which are important for life. Key ideas include
a) photosynthesis is the foundation of virtually all food webs; and
b) photosynthesis and cellular respiration support life processes.

LS.5 The student will investigate and understand that biotic and abiotic factors affect an ecosystem. Key ideas include
a) matter moves through ecosystems via the carbon, water, and nitrogen cycles;
b) energy flow is represented by food webs and energy pyramids; and
c) relationships exist among producers, consumers, and decomposers.

LS.6 The student will investigate and understand that populations in a biological community interact and are interdependent. Key ideas include
a) relationships exist between predators and prey and these relationships are modeled in food webs;
b) the availability and use of resources may lead to competition and cooperation;
c) symbiotic relationships support the survival of different species; and
d) the niche of each organism supports survival.

LS.7 The student will investigate and understand that adaptations support an organism's survival in an ecosystem. Key ideas include
a) biotic and abiotic factors define land, marine, and freshwater ecosystems; and
b) physical and behavioral characteristics enable organisms to survive within a specific ecosystem.

LS.8 The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic and change over time. Key ideas include
a) organisms respond to daily, seasonal, and long-term changes;
b) changes in the environment may increase or decrease population size; and
c) large-scale changes such as eutrophication, climate changes, and catastrophic disturbances affect ecosystems.

LS.9 The student will investigate and understand that relationships exist between ecosystem dynamics and human activity. Key ideas include
a) changes in habitat can disturb populations;
b) disruptions in ecosystems can change species competition; and
c) variations in biotic and abiotic factors can change ecosystems.

LS.10 The student will investigate and understand that organisms reproduce and transmit genetic information to new generations. Key ideas include
a) DNA has a role in making proteins that determine organism traits;
b) the role of meiosis is to transfer traits to the next generation; and
c) Punnett squares are mathematical models used to predict the probability of traits in offspring.

LS.11 The student will investigate and understand that populations of organisms can change over time. Key ideas include
a) mutation, adaptation, natural selection, and extinction change populations;
b) the fossil record, genetic information, and anatomical comparisons provide evidence for evolution; and
c) environmental factors and genetic variation, influence survivability and diversity of organisms.

Physical Science

The Physical Science standards stress an in-depth understanding of the nature and structure of matter and the characteristics of energy. Major areas covered by the standards include the particle nature of matter, the organization and use of the periodic table; physical and chemical changes; energy transfer and transformations; properties of longitudinal and transverse waves; electricity and magnetism; and work, force, and motion. The standards build on skills of systematic investigation with a clear focus on variables and repeated trials. Validating conclusions with evidence and data becomes increasingly important at this level. Mathematics, computational thinking, and experience in the engineering design process gain importance as students advance in their scientific thinking.

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

a) asking questions and defining problems
- ask questions that require empirical evidence to answer
- develop hypotheses indicating relationships between independent and dependent variables
- offer simple solutions to design problems

b) planning and carrying out investigations
- independently and collaboratively plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate and include the safe use of chemicals and equipment
- evaluate the accuracy of various methods for collecting data
- take metric measurements using appropriate tools and technologies
- apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system

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 and consider limitations of data analysis
- apply mathematical concepts and processes to scientific questions
- use data to evaluate and refine design solutions to best meet criteria

d) constructing and critiquing conclusions and explanations
- construct scientific explanations based on valid and reliable evidence obtained from sources (including the students' own investigations)
- construct arguments supported by empirical evidence and scientific reasoning
- generate and compare multiple solutions to problems based on how well they meet the criteria and constraints
- differentiate between a scientific hypothesis, theory, and law

e) developing and using models
   - construct, develop, and use models and simulations to illustrate and/or explain observable and unobservable phenomena
   - evaluate limitations of models

f) obtaining, evaluating, and communicating information
   - read scientific texts, including those adapted for classroom use, to determine the central idea and/or obtain scientific and/or technical information
   - gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication
   - construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning

PS.2 The student will investigate and understand that matter is composed of atoms. Key ideas include
a) our understanding of atoms has developed over time;
b) the periodic table can be used to predict the chemical and physical properties of matter; and
c) the kinetic molecular theory is used to predict and explain matter interactions.

PS.3 The student will investigate and understand that matter has properties and is conserved in chemical and physical processes. Key ideas include
a) pure substances can be identified based on their chemical and physical properties;
b) pure substances can undergo physical and chemical changes that may result in a change of properties;
c) compounds form through ionic and covalent bonding; and
d) balanced chemical equations model the conservation of matter.

PS.4 The student will investigate and understand that the periodic table is a model used to organize elements based on their atomic structure. Key uses include
a) symbols, atomic numbers, atomic mass, chemical groups (families), and periods are identified on the periodic table; and
b) elements are classified as metals, metalloids, and nonmetals.

PS.5 The student will investigate and understand that energy is conserved. Key ideas include
a) energy can be stored in different ways;
b) energy is transferred and transformed; and
c) energy can be transformed to meet societal needs.

PS.6 The student will investigate and understand that waves are important in the movement of energy. Key ideas include

a) energy may be transferred in the form of longitudinal and transverse waves;
b) mechanical waves need a medium to transfer energy;
c) waves can interact; and
d) energy associated with waves has many applications.

PS.7 The student will investigate and understand that electromagnetic radiation has characteristics. Key ideas include

a) electromagnetic radiation, including visible light, has wave characteristics and behavior; and
b) regions of the electromagnetic spectrum have specific characteristics and uses.

PS.8 The student will investigate and understand that work, force, and motion are related. Key ideas include

a) motion can be described using position and time; and
b) motion is described by Newton's laws.

PS.9 The student will investigate and understand that there are basic principles of electricity and magnetism. Key ideas include

a) an imbalance of charge generates static electricity;
b) materials have different conductive properties;
c) electric circuits transfer energy;
d) magnetic fields cause the magnetic effects of certain materials;
e) electric current and magnetic fields are related; and
f) many technologies use electricity and magnetism.

Biology

The Biology standards are designed to provide students with a detailed understanding of living systems. Students investigate biochemical life processes, cellular organization, mechanisms of inheritance, dynamic relationships among organisms, and the changes in organisms through time. Skills necessary to examine scientific explanations, conduct experiments, analyze and communicate information, and gather and use information in scientific literature continues to be important. The importance of scientific research that validates or challenges ideas is emphasized at this level. Tools and technology, including calculators, computers, probeware, and microscopes are used when feasible. Students will use chemicals and equipment safely. Mathematics, computational thinking, and experience in the engineering design process are important as students advance in their scientific thinking.

BIO.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 and/or organisms, from examining models and theories, and/or to seek additional information
   - determine which questions can be investigated within the scope of the school laboratory or field to determine relationships between independent and dependent variables
   - generate hypotheses based on research and scientific principles
   - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated

b) planning and carrying out investigations
   - individually and collaboratively plan and conduct observational and experimental investigations
   - plan and conduct investigations or test design solutions in a safe and ethical manner including considerations of environmental, social, and personal effects
   - determine appropriate sample size and techniques
   - 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
   - use data in building and revising models, supporting an explanation for phenomena, or testing solutions to problems
   - analyze data using tools, technologies, and/or models 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 regarding the relationship between dependent and independent variables

- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including students' own investigations, models, theories, simulations, and peer review
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and design solutions
- compare and evaluate competing arguments or design solutions in light of currently accepted explanations and new scientific evidence
- construct arguments or counterarguments based on data and evidence
- differentiate between a scientific hypothesis and theory

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
- develop and/or use models to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems

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 authoritative sources, assessing the evidence and credibility of each source
- communicate scientific and/or technical information about phenomena in multiple formats

BIO.2 The student will investigate and understand that chemical and biochemical processes are essential for life. Key ideas include
a) water chemistry has an influence on life processes;
b) macromolecules have roles in maintaining life processes;
c) enzymes have a role in biochemical processes;
d) protein synthesis is the process of forming proteins which influences inheritance and evolution; and
e) the processes of photosynthesis and respiration include the capture, storage, transformation, and flow of energy.

BIO.3 The student will investigate and understand that cells have structure and function. Key ideas include
a) the cell theory is supported by evidence;
b) structures in unicellular and multicellular organisms work interdependently to carry out life processes;
c) cell structures and processes are involved in cell growth and division;
d) the structure and function of the cell membrane support cell transport; and
e) specialization leads to the development of different types of cells.

BIO.4 The student will investigate and understand that bacteria and viruses have an effect on living systems. Key ideas include

a) viruses depend on a host for metabolic processes;
b) the modes of reproduction/replication can be compared;
c) the structures and functions can be compared;
d) bacteria and viruses have a role in other organisms and the environment; and
e) the germ theory of infectious disease is supported by evidence.

BIO.5 The student will investigate and understand that there are common mechanisms for inheritance. Key ideas include
a) DNA has structure and is the foundation for protein synthesis;
b) the structural model of DNA has developed over time;
c) the variety of traits in an organism are the result of the expression of various combinations of alleles;
d) meiosis has a role in genetic variation between generations; and
e) synthetic biology has biological and ethical implications.

BIO.6 The student will investigate and understand that modern classification systems can be used as organizational tools for scientists in the study of organisms. Key ideas include
a) organisms have structural and biochemical similarities and differences;
b) fossil record interpretation can be used to classify organisms;
c) developmental stages in different organisms can be used to classify organisms;
d) Archaea, Bacteria, and Eukarya are domains based on characteristics of organisms;
e) the functions and processes of protists, fungi, plants, and animals allow for comparisons and differentiation within the Eukarya kingdoms; and
f) systems of classification are adaptable to new scientific discoveries.

BIO.7 The student will investigate and understand that populations change through time. Key ideas include
a) evidence is found in fossil records and through DNA analysis;
b) genetic variation, reproductive strategies, and environmental pressures affect the survival of populations;
c) natural selection is a mechanism that leads to adaptations and may lead to the emergence of new species; and
d) biological evolution has scientific evidence and explanations.

BIO.8 The student will investigate and understand that there are dynamic equilibria within populations, communities, and ecosystems. Key ideas include
a) interactions within and among populations include carrying capacities, limiting factors, and growth curves;
b) nutrients cycle with energy flow through ecosystems;
c) ecosystems have succession patterns; and
d) natural events and human activities influence local and global ecosystems and may affect the flora and fauna of Virginia.

Chemistry

The Chemistry standards are designed to provide students with a detailed understanding of the interaction between matter and energy. This interaction is investigated using experimentation, mathematical reasoning, and problem-solving. Areas of study include atomic theory, chemical bonding, chemical reactions, molar relationships, kinetic molecular theory, solutions and thermodynamics. Concepts are illustrated with current practical applications that should include examples from environmental, nuclear, organic, and biochemistry content areas. Technology, including graphing calculators, computers, and probeware are used when feasible. Students will use chemicals and equipment safely when applying chemistry content in a laboratory setting. Mathematics, computational thinking, and experience with the engineering design process are essential as students advance in their scientific thinking.

CH.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, unexpected results, and/or to seek additional information
- determine which questions can be investigated within the scope of the school laboratory
- make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
- generate hypotheses based on research and scientific principles
- define design problems that involve the development of a process or system with interacting components, criteria and constraints

b) planning and carrying out investigations
- individually and collaboratively plan and conduct observational and experimental investigations
- plan and conduct investigations or test design solutions in a safe manner, including planning for response to emergency situations
- select and use appropriate tools and technology to collect, record, analyze, and evaluate data

c) interpreting, analyzing and evaluating data
- record and present data in an organized format that communicates relationships and quantities in appropriate mathematical or algebraic forms
- use data in building and revising models, supporting explanations for phenomena, or testing solutions to problems
- solve problems using mathematical manipulations including the International System of Units (SI), scientific notation, derived units, significant digits, and dimensional analysis
- analyze data using tools, technologies, and/or models (e.g., computational, mathematical) to make valid and reliable scientific claims or determine an optimal design solution
- analyze data graphically and use graphs to make predictions

- differentiate between accuracy and precision of measurements
- consider limitations of data analysis when analyzing and interpreting data
- analyze data to optimize a design

d) constructing and critiquing conclusions and explanations
- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena or design solutions
- compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence
- construct arguments or counterarguments based on data and evidence
- differentiate between 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
- use models and simulations to visualize and explain the movement of particles, to represent chemical reactions, to formulate mathematical equations, and to interpret data sets

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 authoritative 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

CH.2 The student will investigate and understand that elements have properties based on their atomic structure. The periodic table is an organizational tool for elements based on these properties. Key information pertaining to the periodic table includes

a) average atomic mass, isotopes, mass number, and atomic number;
b) nuclear decay;
c) trends within groups and periods including atomic radii, electronegativity, shielding effect, and ionization energy;
d) electron configurations, valence electrons, excited electrons, and ions; and
e) historical and quantum models.

CH.3 The student will investigate and understand that atoms are conserved in chemical reactions. Knowledge of chemical properties of the elements can be used to describe and predict chemical interactions. Key ideas include

a) chemical formulas are models used to represent the number of each type of atom in a substance;

b) substances are named based on the number of atoms and the type of interactions between atoms;
c) balanced chemical equations model rearrangement of atoms in chemical reactions;
d) atoms bond based on electron interactions;
e) molecular geometry is predictive of physical and chemical properties; and
f) reaction types can be predicted and classified.

CH.4 The student will investigate and understand that molar relationships compare and predict chemical quantities. Key ideas include
a) Avogadro's principle is the basis for molar relationships; and
b) stoichiometry mathematically describes quantities in chemical composition and in chemical reactions.

CH.5 The student will investigate and understand that solutions behave in predictable and quantifiable ways. Key ideas include
a) molar relationships determine solution concentration;
b) changes in temperature can affect solubility;
c) extent of dissociation defines types of electrolytes;
d) pH and pOH quantify acid and base dissociation; and
e) colligative properties depend on the extent of dissociation.

CH.6 The student will investigate and understand that the phases of matter are explained by the kinetic molecular theory. Key ideas include
a) pressure and temperature define the phase of a substance;
b) properties of ideal gases are described by gas laws; and
c) intermolecular forces affect physical properties.

CH.7 The student will investigate and understand that thermodynamics explains the relationship between matter and energy. Key ideas include
a) heat energy affects matter and interactions of matter;
b) heating curves provide information about a substance;
c) reactions are endothermic or exothermic;
d) energy changes in reactions occur as bonds are broken and formed;
e) collision theory predicts the rate of reactions;
f) rates of reactions depend on catalysts and activation energy; and
g) enthalpy and entropy determine the extent of a reaction.

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.

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 effects
- 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 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, and peer review
   - apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena or design solutions
   - construct arguments or counterarguments 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

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 explains 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 from space exploration has increased our understanding of the structure and nature of our universe.

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.

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) minerals originate and are formed in specific ways.

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 are 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.

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 effects are considerations when using resources;
c) use of Virginia resources has an effect on the environment and the economy; and
d) all energy sources have environmental and economic effects.

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 and influence the distribution of materials in Earth's layers, and may impact the magnetic field;
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.

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

a) water influences 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 affect freshwater resources, including water locations, quality, and supply; and
d) stream processes and dynamics affect the major watershed systems in Virginia, including the Chesapeake Bay and its tributaries.

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.

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 affect 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, affect oceans and the coastal zone including the Chesapeake Bay.

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 the atmospheric composition;
c) natural events and human actions may stress atmospheric regulation mechanisms; and
d) human actions, including economic and policy decisions, affect the atmosphere.

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 natural and human activity affect global climate.

Physics

The Physics standards emphasize a more complex understanding of experimentation, the analysis of data, and the use of reasoning and logic to evaluate scientific evidence and develop engineering design solutions. The use of mathematics, including algebra and trigonometry is important, but conceptual understanding of physical systems remains a primary concern. Students build on basic physical science principles by exploring in-depth the nature and characteristics of energy and its dynamic interaction with matter. Key areas covered by the standards include force and motion, energy transformations, wave phenomena and the electromagnetic spectrum, electricity, fields, and non-Newtonian physics. Technology, including graphing calculators, computers, and probeware are used when feasible. Students will use equipment safely. Mathematics, computational thinking, and experience in the engineering design process are essential as students advance in their scientific thinking.

PH.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, unexpected results, and/or to seek additional information
   - determine which questions can be investigated within the scope of the school laboratory
   - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
   - generate hypotheses based on research and scientific principles
   - define design problems that involves the development of a process or system with interacting components and criteria and constraints

b) planning and carrying out investigations
   - individually and collaboratively plan and conduct observational and experimental investigations
   - plan and conduct investigations or test design solutions in a safe manner
   - select and use appropriate tools and technology to collect, record, analyze, and evaluate data

c) interpreting, analyzing, and evaluating data
   - record and present data in an organized format that communicates relationships and quantities in appropriate mathematical or algebraic forms
   - use data in building and revising models, supporting an explanation for phenomena, or testing solutions to problems
   - analyze data using tools, technologies, and/or models (e.g., computational, mathematical, statistical) in order to make valid and reliable scientific claims or determine an optimal design solution
   - analyze data graphically and use graphs to make predictions
   - consider limitations of data analysis when analyzing and interpreting data
   - evaluate the effects of new data on a working explanation and/or model of a proposed process or system

- analyze data to optimize a design

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
   - apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena or design solutions
   - compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence
   - construct arguments or counterarguments based on data and evidence
   - differentiate between scientific hypothesis, theory, and law

e) developing and using models
   - evaluate the merits and limitations of models
   - identify and communicate components of a system orally, graphically, textually, and mathematically
   - develop and/or use models (including mathematical and computational) and simulations to visualize, explain, and predict phenomena and to interpret data sets

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 authoritative 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

PH.2 The student will investigate and understand, through mathematical and experimental processes, that there are relationships between position and time. Key topics include
a) displacement, velocity, and uniform acceleration;
b) linear motion;
c) uniform circular motion; and
d) projectile motion.

PH.3 The student will investigate and understand, through mathematical and experimental processes, that there are relationships among force, mass, and acceleration. Key laws include
a) Newton’s laws of motion; and
b) Newton’s law of universal gravitation.

PH.4 The student will investigate and understand, through mathematical and experimental processes, that conservation laws govern all interactions. Key ideas include
a) momentum is conserved unless an impulse acts on the system; and

b) mechanical energy is conserved unless work is done on, by, or within the system.

PH.5 The student will investigate and understand, through mathematical and experimental processes, that waves transmit energy and move in predictable patterns. Key ideas include
a) waves have specific characteristics;
b) wave interactions are part of everyday experiences; and
c) light and sound transmit energy as waves.

PH.6 The student will investigate and understand, through mathematical and experimental processes, that optical systems form a variety of images. Key ideas include
a) the laws of reflection and refraction describe light behavior; and
b) ray diagrams model light as it travels through different media.

PH.7 The student will investigate and understand, through mathematical and experimental processes, that fields provide a unifying description of force at a distance. Key ideas include
a) gravitational, electric, and magnetic forces can be described using the field concept; and
b) field strength diminishes with increased distance from the source.

PH.8 The student will investigate and understand, through mathematical and experimental processes, that electrical circuits are a system used to transfer energy. Key ideas include
a) circuit components have different functions within the system;
b) Ohm's law relates voltage, current, and resistance;
c) different types of circuits have different characteristics and are used for different purposes;
d) electrical power is related to the elements in a circuit; and
e) electrical circuits have everyday applications.

PH.9 The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied in Newtonian physics. Topics, such as these listed, may be included.
a) wave/particle duality;
b) quantum mechanics and uncertainty;
c) relativity;
d) nuclear physics;
e) solid state physics;
f) nanotechnology;
g) superconductivity;
h) the standard model; and
i) dark matter and dark energy.