Board of Education Agenda Item

Item: I. **Date:** November 18, 2010

Topic: Final Review of Proposed Revised Curriculum Framework for 2010 *Science Standards of Learning*

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Origin:

____ Topic presented for information only (no board action required)

_X_ Board review required by
- _X_ State or federal law or regulation
- ____ Board of Education regulation
- ____ Other: _____

_X_ Action requested at this meeting ___Action requested at future meeting:

Previous Review/Action:

____ No previous board review/action

_X_ Previous review/action
date September 23, 2010
action Board of Education accepted the Proposed Revised Curriculum Framework for 2010 *Science Standards of Learning* for first review and public comment.

Background Information:
New academic content *Science Standards of Learning* were developed in 1995 and revised in 2003. The Standards of Quality require the Board of Education to review the Standards of Learning on a regular schedule. On January 14, 2010, the Board approved the 2010 *Science Standards of Learning*. In accordance with the plan, the Department of Education then took the following steps to produce a draft of the proposed revised Curriculum Framework for the 2010 *Science Standards of Learning* for the Board's first review:

- Selected a review committee that consisted of individuals solicited from school divisions as well as other stakeholder groups to participate in the process;
- Met with the review committee during June 2010; and
- Developed a draft of the proposed revised Curriculum Framework for the 2010 *Science Standards of Learning*.

On September 23, 2010, the Virginia Board of Education accepted for first review the proposed revised Curriculum Framework for the 2010 *Science Standards of Learning*. A public comment period was held from September 24, 2010, through October 25, 2010. A summarized review of public comment is contained in Attachment A.

Summary of Major Elements:
The proposed revised Curriculum Framework for the 2010 *Science Standards of Learning* in Attachment B contains minimal changes made as a result of public comment. These changes are indicated by double strikethrough and underline and include:

- revisions of language for clarification and/or specification of content; and
- addition of essential understandings information for instruction, assessment, and/or vertical alignment.

Superintendent's Recommendation:
The Superintendent of Public Instruction recommends that the Board of Education accept for final review the proposed revised Curriculum Framework for the 2010 *Science Standards of Learning* and permit the Department of Education to make technical edits as needed.

Impact on Resources:
This responsibility can be absorbed by the agency's existing resources at this time.

Timetable for Further Review/Action:
Following the Board of Education's acceptance of the 2010 *Science Standards of Learning* Curriculum Framework, the Department of Education will post the document on the Department's Curriculum Framework Web site.

Attachment A

Summary of Comments on the Proposed Revised Curriculum Framework for 2010 *Science Standards of Learning*

Summary of Online Comments

A total of 212 comments were received during the public comment period from September 23, 2010, through October 25, 2010. This represents 13 individuals, two school divisions, one school, one professional organization, and two business/industry councils.

The following table indicates the number of comments received.

Grade Band, Level, and Course	Number of Comments
K-12 General	2
Kindergarten	12
Grade 1	13
Grade 2	9
Grade 3	20
Grade 4	38
Grade 5	29
Grade 6	9
Life Science	5
Physical Science	13
Earth Science	38
Biology	6
Chemistry	9
Physics	9
Total	**212**

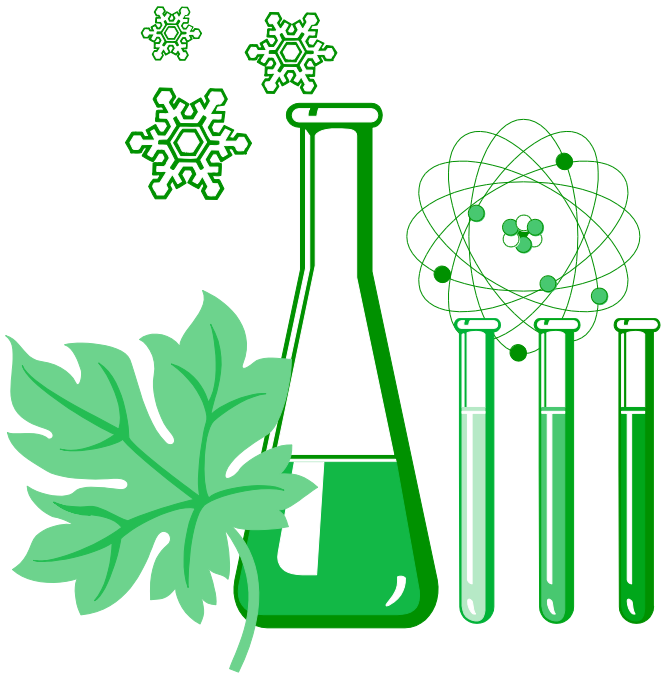
Many of the comments were positive regarding the revisions to the first draft of the Curriculum Framework. Comments included:

- praise for the inclusion of detail associated with the nature of science;
- appreciation for the inclusion of the use of models, simulations, and current applications;
- requests that correct terminology be used when referring to energy;
- appreciation that terminology is now consistent from kindergarten through grade 12;
- appreciation that additional content detail has been included for grades kindergarten through five;
- request that the information about the magnetic compass be modified in kindergarten and grade two;
- concern that information about the particle nature of light had not been included in grade five;
- praise for the inclusion of the chart with details about the characteristics of gases, liquids, and solids in grade five;
- praise for the inclusion of the study of nanotechnology and suggestion that it also be included in physical science;

- request that the importance of the pH scale be put back in the biology Curriculum Framework;
- concern that work with friction no longer is included in physics; and
- praise from the technology industry community that the changes in the Curriculum Framework will help prepare the future work force.

Changes that were made to the proposed revised Curriculum Framework based on the public comments received focused on the following areas.

- Updates were made to add clarity to detail.
- Attention was given to consistency of terminology used and accuracy of terminology definitions so that the integrity of the science content progressions K-12 was maintained.
- Additions were made to content detail to assure that adequate background information was included and that content detail addressed all revisions that had been made to the 2010 *Science Standards of Learning*.
- Additions or deletions were made when needed to ensure content accuracy and to remove any duplication of details.



Science Standards of Learning Curriculum Framework

Kindergarten

Final Review
November 18, 2010

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Board of Education
Richmond, Virginia
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by the

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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Kindergarten
Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student ~~should~~ will be able to do when conducting activities and investigations and represents the student understanding of the nature of science. The various skill categories are described in the "Investigate and Understand" section of the Introduction to the *Science Standards of Learning*, and the skills in science standard K.1 represent more specifically what a student should achieve during the course of instruction in kindergarten. Across the grade levels, the skills in the first standards form a nearly continuous sequence of investigative skills and an understanding of the nature of science. ~~(Please note Appendix, "Science Skills, Scope, & Sequence.")~~ It is important that the classroom teacher understand how the skills in standards K.1 and K.2 are a key part of this sequence (i.e., 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). ~~It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in the "Scientific Investigation, Reasoning, and Logic" strand.~~

K.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) basic characteristics or properties of objects are identified by direct observation; b) observations are made from multiple positions to achieve different perspectives; c) a set of objects is sequenced according to size; d) a set of objects is separated into two groups based on a single physical characteristic; e) nonstandard units are used to measure the length, mass, and volume of common objects; f) observations and predictions are made for an unseen member in a sequence of objects; g) a question is developed and predictions are made from one or more observations; h) observations are recorded; i) picture graphs are constructed; j) unusual or unexpected results in an activity are recognized; and k) objects are described both pictorially and verbally.

~~Understanding the Standard~~ Overview

~~The skills defined in~~ Standard K.1 ~~are~~ is intended to develop ~~the~~ investigative and inquiry ~~components~~ skills and an understanding of the nature of science ~~of all of the other kindergarten standards (i.e., K.2–K.10)~~. Standard K.1 describes the range of inquiry skills and the level of proficiency in using those skills ~~that~~ students should achieve, and the components of the nature of science that should be developed and reinforced in the context of science concepts developed in kindergarten. **Standard K.1 does not require a discrete unit be taught on scientific investigation and the nature of science because the ~~inquiry~~ skills that make up the standard should be incorporated in all the other kindergarten science standards.** It is also intended that by participating in activities and experiences that develop these skills, students will achieve a preliminary understanding of scientific inquiry and the nature of science and more fully grasp the content-related concepts.

K.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) basic characteristics or properties of objects are identified by direct observation;
b) observations are made from multiple positions to achieve different perspectives;
c) a set of objects is sequenced according to size;
d) a set of objects is separated into two groups based on a single physical characteristic;
e) nonstandard units are used to measure the length, mass, and volume of common objects;
f) observations and predictions are made for an unseen member in a sequence of objects;
g) a question is developed and predictions are made from one or more observations;
h) observations are recorded;
i) picture graphs are constructed;
j) unusual or unexpected results in an activity are recognized; and
k) objects are described both pictorially and verbally.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts: a) the natural world is understandable; b) science is based on evidence, both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected. e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. In kindergarten, an emphasis should be placed on concepts a, b, and e. • Science assumes that the natural world is understandable. Scientific inquiry can provide explanations about nature. This expands students' ~~knowledge~~ thinking from just a knowledge of facts to understanding ~~why~~ how ~~the~~ facts are relevant to everyday life. • Science demands evidence. Scientists develop their ideas based on	In order to meet this standard, it is expected that students ~~should be able to~~ will • observe objects and describe their basic properties. These properties include color, shape (circle, triangle, square, and rectangle), size (big, little, large, small), texture (rough, smooth, hard, soft), and weight (heavy, light). • observe an object or objects from multiple positions to achieve different perspectives. In order to accomplish this, the student should look at the object from top, bottom, front, and back, and describe what he/she sees. • arrange a set of objects in sequence according to size. • separate a set of objects into two groups based on a single physical ~~attribute~~ characteristic, including ~~size,~~ color, shape, size, texture, and weight. • measure common objects with nonstandard units. Examples of nonstandard units include hands, pennies, and paper clips for ~~measuring~~ determining length; holding and comparing two different objects for ~~measuring~~ determining mass; and liquids put in drinking

K.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) basic characteristics or properties of objects are identified by direct observation;
b) observations are made from multiple positions to achieve different perspectives;
c) a set of objects is sequenced according to size;
d) a set of objects is separated into two groups based on a single physical characteristic;
e) nonstandard units are used to measure the length, mass, and volume of common objects;
f) observations and predictions are made for an unseen member in a sequence of objects;
g) a question is developed and predictions are made from one or more observations;
h) observations are recorded;
i) picture graphs are constructed;
j) unusual or unexpected results in an activity are recognized; and
k) objects are described both pictorially and verbally.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
evidence and they change their ideas when new evidence becomes available or the old evidence is viewed in a different way. • Science is a complex social endeavor. It is a complex social process for producing knowledge about the natural world. Scientific knowledge represents the current consensus as to what is the best explanation for phenomena in the natural world. This consensus does not arise automatically, since scientists with different backgrounds from all over the world may interpret the same data differently. To build a consensus, scientists communicate their findings to other scientists and attempt to replicate one another's findings. In order to model the work of professional scientists, it is essential for kindergarten students to engage in frequent discussions with peers about their understanding of their investigations. • Observation is an important ~~way~~ skill that enables us to learn about the world. Observations are expressed as descriptive statements about natural phenomena that are accessible to the senses either directly or with the use of technology. Through observation one can learn to compare, contrast, and note similarities and differences. • An object can appear very different depending on how it is oriented. To describe an object fully and accurately, it should be observed from	cups ~~and compared~~ for ~~measuring~~ determining volume. • predict an unseen member in a sequence of objects to complete a pattern. • develop a question from one or more observations about the natural world. • make a prediction based on observations. • record observations using pictures. • construct picture graphs using 10 or fewer units. • identify unusual or unexpected results in an activity. • describe objects both pictorially and verbally.

K.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) basic characteristics or properties of objects are identified by direct observation;
b) observations are made from multiple positions to achieve different perspectives;
c) a set of objects is sequenced according to size;
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e) nonstandard units are used to measure the length, mass, and volume of common objects;
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k) objects are described both pictorially and verbally.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
several different positions. • Putting objects in a sequence allows one to understand how things are related. A sequence can ~~show how things can change a little at a time~~ illustrate incremental changes over time. • A nonstandard unit of measure, such as the length of a paper clip, can be used to describe and communicate the dimensions of an object. For the nonstandard unit to be most useful, it should be consistent and easily applied. • Sequenced objects or events can show patterns over time. Occasionally, items are missing in a sequence, but observations of patterns in the sequence can offer clues to predict the item(s) that are missing. • Observations about familiar objects or events often lead to the development of predictions and important questions that can spark further investigation. • Observations that are made can be recorded in a variety of ways. Picture graphs are useful ways to display and report information. • It is important to observe the results of an investigation carefully. Results that are unexpected or unusual may be of interest for further study.	

K.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) basic characteristics or properties of objects are identified by direct observation; b) observations are made from multiple positions to achieve different perspectives; c) a set of objects is sequenced according to size; d) a set of objects is separated into two groups based on a single physical characteristic; e) nonstandard units are used to measure the length, mass, and volume of common objects; f) observations and predictions are made for an unseen member in a sequence of objects; g) a question is developed and predictions are made from one or more observations; h) observations are recorded; i) picture graphs are constructed; j) unusual or unexpected results in an activity are recognized; and k) objects are described both pictorially and verbally.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• Observations can be communicated through pictures and discussions.	

K.2	The student will investigate and understand that humans have senses that allow them to seek, find, take in, and react or respond to information in order to learn about their surroundings. Key concepts include a) the five senses and corresponding sensing organs; and b) sensory descriptors used to describe common objects and phenomena.

~~Understanding the Standard~~ Overview

~~The second standard at the kindergarten level~~ Standard K.2 is very closely related to K.1 in developing the inquiry skill of observation ~~developed in K.1~~. This standard focuses on the senses — sight, smell, hearing, touch, and taste. Standard K.2 focuses on student understanding that each sensing organ (eyes, ears, nose, tongue, and skin) is associated with a sense. It is important to emphasize that ~~one~~ a student should never taste, touch, or sniff something when the identity is unknown or has any potential danger.

K.2	The student will investigate and understand that humans have senses that allow them to seek, find, take in, and react or respond to information in order to learn about their surroundings. Key concepts include a) the five senses and corresponding sensing organs; and b) sensory descriptors used to describe common objects and phenomena.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • A particular sensing organ (eye~~s~~, ear~~s~~, nose, tongue, and skin) is associated with each of the five senses. • Using the senses, we can make careful observations about the world ~~and communicate those observations through descriptors~~. • To communicate what is observed, descriptors should be used.	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify and describe the five senses: taste, touch, smell, hearing, and sight. • match each sensing organ (eye~~s~~, ear~~s~~, nose, tongue, and skin) with its associated sense. • match sensory descriptors with the senses (**taste**: sweet, sour, bitter, salty; **touch**: rough, smooth, hard, soft, cold, warm, hot; **hearing**: loud, soft, high, low; **sight**: bright, dull, color, black, ~~and~~ white; **smell**: strong, faint, bad, and good.)

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

K.3	The student will investigate and understand that magnets have an effect on some materials, make some things move without touching them, and have useful applications. Key concepts include a) magnetism and its effects; and b) useful applications of magnetism.

~~Understanding the Standard~~ Overview

Magnets have an effect on certain metals and can cause objects to move without physically touching them. Standard K.3 focuses on developing a basic understanding of magnetism that will be expanded in standards 2.2 and 4.3. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

K.3 The student will investigate and understand that magnets have an effect on some materials, make some things move without touching them, and have useful applications. Key concepts include
a) magnetism and its effects; and
b) useful applications of magnetism.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • A magnet has two ends called poles, one of which is called a north pole or north-seeking pole, and the other is called a south pole or south-seeking pole. • The north pole of one magnet attracts the south pole of a second magnet, while the north pole of one magnet repels the other magnet's north pole. One way to state this is that like poles repel and unlike poles attract. Repulsion is the force that pushes like poles of magnets apart. • A magnet creates an invisible area of magnetism all around it called a magnetic field. • The north ~~pole~~ end of a magnetic compass always points roughly toward Earth's North Pole and ~~vice-versa~~ the south end of the compass needle always points toward Earth's South Pole. That is because Earth itself contains magnetic materials and behaves like a gigantic magnet. • If you cut a bar magnet in half, you get two new, smaller magnets, each with its own north and south pole. • Magnets will attract certain metals (iron-bearing, nickel, and cobalt). • Magnets have an effect on some items and can cause them to move. Some items are not affected by magnets and remain stationary. • Because some metals are attracted to magnets, magnets have many simple useful applications in the home such as can openers, magnetized screwdrivers, magnetic cabinet door latches, and magnetic games. • The force of a magnet can move something without actually touching it. • Students will be introduced to the vocabulary attract/repel,	In order to meet this standard, it is expected that students ~~should be able to~~ will • predict and test which common objects will be attracted to magnets and which will not be attracted to magnets. • classify objects as being attracted or not attracted to magnets, such as an iron nail, an iron-bearing paper clip, cereal, and a book. • ~~explain in their own words essential vocabulary, including the concepts of attraction/nonattraction, push/pull, attract/repel, and metal/nonmetal.~~ • explain in their own words how an object such as an iron nail, an iron-bearing paper clip, cereal, or a book is affected by a magnet. • identify items in the home or school that contain a magnet or magnets, such as can openers, magnetized screwdrivers, magnetic games, magnetic cabinet door latches, ~~and~~ refrigerator magnets, and magnetic letters. • ~~evaluate the importance and usefulness of magnets in the home.~~

K.3 The student will investigate and understand that magnets have an effect on some materials, make some things move without touching them, and have useful applications. Key concepts include a) magnetism and its effects; and b) useful applications of magnetism.	
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
nonattraction, metal, and nonmetal in grade two. The focus of the investigations in this standard should be on the concepts, not the terminology.	

Kindergarten
Science Strand

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, ~~states~~ phases of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure ~~of~~ and classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

K.4	The student will investigate and understand that the position, motion, and physical properties of an object can be described. Key concepts include a) colors of objects; b) shapes and forms of objects; c) textures and feel of objects; d) relative sizes and weights of objects; and e) relative positions and speed of objects.

~~Understanding the Standard~~ Overview

Standard K.4 focuses on student understanding that all objects have physical properties, which include color, shape or form, texture, and size. Position and speed, though not physical properties, can also be observed and described. A basic understanding of physical properties provides a foundation for observing, investigating, and studying matter. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

K.4 The student will investigate and understand that the position, motion, and physical properties of an object can be described. Key concepts include
a) colors of objects;
b) shapes and forms of objects;
c) textures and feel of objects;
d) relative sizes and weights of objects; and
e) relative positions and speed of objects.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following~~: • An object may have many properties that can be observed and described. • An ~~Objects~~ object can be described readily in terms of color~~, shape, and texture~~. • Visible light waves are the only electromagnetic waves that we can see with the naked eye. We see these waves as the colors of the rainbow. Each color has a different wavelength. Red has the longest wavelength and violet has the shortest wavelength. • When all the waves are seen together, they make white light. When white light shines through a prism, the white light is broken apart into colors. Water vapor in the atmosphere can act as a prism and break apart the white light, creating a rainbow. • The order of the colors in the visible spectrum are red, orange, yellow, green, blue, and violet. Most scientists no longer include the color indigo, which used to be included between blue and violet. • ~~Indigo and~~ At the kindergarten level, violet is referred to as purple. It is not required at the kindergarten level that students know the term violet. ~~are not required at the kindergarten level.~~ • Black and white are not spectral colors, but students should recognize them by name. Black is the total absence of light and is when a material absorbs all the light. White is a reflection of all visible light together. • An object can be described in terms of shape, size, and texture.	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify and name ~~eight~~ six basic colors, including red, orange, yellow, green, blue, and purple~~.~~; and identify and name black and white. • identify and name a circle, triangle, square, and rectangle. • compare and contrast objects that are flexible, stiff, straight, and/or curved. • compare and contrast objects that are rough, smooth, hard, and/or soft. • compare objects using the concepts of heavy/light, long/short, wide/thin, big/little, and large/small. • measure objects, using nonstandard units, and direct comparisons. • identify the position of an object, using position words over/under, in/out, above/below, and left/right. • group objects according to their speed — fast or slow.

K.4	The student will investigate and understand that the position, motion, and physical properties of an object can be described. Key concepts include a) colors of objects; b) shapes and forms of objects; c) textures and feel of objects; d) relative sizes and weights of objects; and e) relative positions and speed of objects.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• An object can be described according to its position relative to another object and according to its motion. • Two different objects can have some of the same physical properties and some different physical properties.	

K.5	The student will investigate and understand that water flows and has properties that can be observed and tested. Key concepts include a) water occurs in different phases; b) water flows downhill; and c) some materials float in water, while others sink.

~~Understanding the Standard~~ Overview

Standard K.5 focuses on student understanding that water has identifying properties that can be observed and described. This standard serves as a basis for understanding physical properties and ~~states~~ phases of matter. Related primary standards include 1.3, 2.3, ~~and~~ 3.3, 5.4, and 6.5. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

K.5 The student will investigate and understand that water flows and has properties that can be observed and tested. Key concepts include
a) water occurs in different phases;
b) water flows downhill; and
c) some materials float in water, while others sink.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Water can be a solid, liquid, or gas. • The ~~state~~ phase of water can be changed by heating or cooling it. • The natural flow of water is from a higher to a lower level. • Some objects float in water, while others do not.	In order to meet this standard, it is expected that students ~~should be able to~~ will • ~~identify~~ classify examples of the different ~~states~~ phases of water (solid, liquid, and gas). • ~~classify examples of different states of matter as solid, liquid, or gas.~~ • describe the natural flow of water. • predict where a stream of water will flow. • predict whether items will float or sink when placed in water. Items to use include wood, metal, ~~fruits,~~ paper, and plastics.

Life Processes

This strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards K.6, K.7, 1.4, 1.5, 2.4, 3.4, and 4.4.

K.6	The student will investigate and understand the differences between living organisms and nonliving objects. Key concepts include a) all things can be classified as living or nonliving; and b) living organisms have certain characteristics that distinguish them from nonliving objects including growth, movement, response to the environment, having offspring, and the need for food, air, and water.

~~Understanding the Standard~~ Overview

Standard K.6 focuses on student understanding that living organisms have identifying properties that distinguish them from nonliving objects and those properties can be observed and described. This standard serves as a basis for understanding the differences between living organisms and nonliving objects, and the interactions between living and nonliving things. Related elementary standards include 1.4, 1.5, 2.5, 3.4, and 4.4. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

K.6	The student will investigate and understand the differences between living organisms and nonliving objects. Key concepts include a) all things can be classified as living or nonliving; and b) living organisms have certain characteristics that distinguish them from nonliving objects including growth, movement, response to the environment, having offspring, and the need for food, air, and water.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Living is used to describe anything that is or has ever been alive (e.g., dog, flower, seed, log). • Nonliving is used to describe anything that is not now nor has ever been alive (e.g., rock, mountain, glass, wristwatch). • All living things grow, breathe, reproduce, excrete, respond to stimuli, and have similar basic needs like nourishment.	In order to meet this standard, it is expected that students will • identify and describe the basic characteristics of living things (growth, movement, response to the environment, having offspring, and the need for food, air, and water). • identify living organisms and nonliving objects found at home and at school. • classify items by living or nonliving.

K.7	The student will investigate and understand basic needs and life processes of plants and animals. Key concepts include a) animals need adequate food, water, shelter, air, and space to survive; b) plants need nutrients, water, air, light, and a place to grow to survive; c) plants and animals change as they grow, have varied life cycles, and eventually die; and d) offspring of plants and animals are similar but not identical to their parents or to one another.

~~Understanding the Standard~~ Overview

Standard ~~K.6~~ K.7 focuses on student understanding that all living things have basic life needs and life processes. This standard introduces basic life science concepts that progress through high school ~~B~~biology. ~~K.6~~ K.7 is very closely related to the concepts presented in 1.4 and 1.5. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

K.7 The student will investigate and understand basic needs and life processes of plants and animals. Key concepts include

a) animals need adequate food, water, shelter, air, and space to survive;
b) plants need nutrients, water, air, light, and a place to grow to survive;
c) plants and animals change as they grow, have varied life cycles, and eventually die; and
d) offspring of plants and animals are similar but not identical to their parents or to one another.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Plants and animals change as they grow. • Animals need adequate food, water, shelter, air, and space to survive. • Some animals are terrestrial animals, some animals are aquatic animals, and some are both. Terrestrial animals get their oxygen from the air they breathe and aquatic animals extract oxygen from water. • In order to survive, plants ~~and animals~~ need ~~food~~ nutrients, water, ~~and gases in the air to live~~ air, light, and a place that has adequate space for them to grow. ~~(Many animals and plants that live in water use the gases that are dissolved in the water.)~~ • Plants provide food for people and animals. • Some plants are terrestrial plants and some are aquatic plants. • Plants ~~make the~~ release oxygen as a product of photosynthesis and ~~that~~ oxygen is then used by other living things ~~breathe~~. ~~They produce the oxygen as part of the process of photosynthesis.~~ Carbon dioxide from the air enters a leaf through the stomata. Oxygen is produced by plants as a waste product and is released into the air through the stomata. • Plants and animals ~~live~~ change as they grow and eventually die. This is part of their life cycle. The life cycles of plants and animals vary by species. • Many offspring of plants and animals are like their parents but not identical to them or to one another.	In order to meet this standard, it is expected that students ~~should be able to~~ will • describe the life needs of animals ~~and plants~~. The life needs are food, water, ~~and air~~ shelter, air, and space. • describe the life needs of plants. The life needs are nutrients, water, air, light, and a place that has adequate space for them to grow. • predict what will happen to animals and plants if life needs are not met. • describe some simple changes animals ~~and plants~~ undergo during the life cycles. ~~For animals t~~This may include changes in their body size, color, ~~body~~ covering, ~~and overall size~~ or shape. ~~For plants this may include size, presence of leaves and branches, and ability to produce flowers and fruits.~~ • describe some simple changes that plants undergo during their life cycles. This may include size, presence of leaves and branches, fruits, and seeds. • compare and contrast young plants and animals with their parents, using pictures and/or live organisms.

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of relationships within and among Earth and space systems. The topics developed include shadows; relationships between the sun and the Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards ~~K.7~~, K.8, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

K.8	The student will investigate and understand that shadows occur when light is blocked by an object. Key concepts include a) shadows occur in nature when sunlight is blocked by an object; and b) shadows can be produced by blocking artificial light sources.

~~Understanding the Standard~~ Overview

Standard ~~K.7~~ K.8 focuses on student understanding that shadows are produced when objects block light. This is a key concept for ~~student's~~ students' future understanding of more complex Earth and physical science concepts such as night and day and eclipses. Within the primary grades, related concepts are found in standards 1.6 and 3.8. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

K.8 The student will investigate and understand that shadows occur when light is blocked by an object. Key concepts include
a) shadows occur in nature when sunlight is blocked by an object; and
b) shadows can be produced by blocking artificial light sources.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • A shadow is an image of an object created when light is blocked by that object. • Shadows can occur whenever light is present. • People can make shadows. • Living and nonliving things can make shadows.	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify a shadow ~~or variety of shadows~~. • describe how ~~to make a~~ shadows occur. • identify and describe sources of light — sun, electric lights, and flashlights — that can produce shadows. • match objects with the shadow they would create. • ~~analyze how~~ demonstrate that shadows change as the direction of the light source changes.

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living things. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, our solar system, and change in ~~the~~ Earth's surface over time. This strand includes science standards ~~K.8,~~ K.9, K.10, 1.7, 2.7, 3.8, 3.9, 4.7, 4.8, and 5.7.

K.9	The student will investigate and understand that there are simple repeating patterns in his/her daily life. Key concepts include a) weather observations; b) the shapes and forms of many common natural objects including seeds, cones, and leaves; and c) animal and plant growth.

~~Understanding the Standard~~ Overview

Standard ~~K.8~~ K.9 focuses on student understanding of basic patterns in daily life. Careful observations of patterns help predict events. Patterns are found in weather; in natural objects, including seeds, cones, and leaves; in the growth of animals and plants; and in daily routines. The basic kindergarten concepts related to patterns will be further developed in the primary grades, especially basic concepts of cycles, sequences, and rate. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

K.9 The student will investigate and understand that there are simple repeating patterns in his/her daily life. Key concepts include
a) weather observations;
b) the shapes and forms of many common natural objects including seeds, cones, and leaves; and
c) animal and plant growth.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • One can make simple predictions in weather patterns. On a cloudy, warm day, it may rain. On a cloudy day that is very cold, it may snow. On a clear day there most likely will be no rain or snow. • As animals and plants grow, they get larger according to a pattern. • Natural objects such as leaves, seeds, and cones have patterns we can see. • ~~Home and school routines frequently follow a pattern.~~	In order to meet this standard, it is expected that students ~~should be able to~~ will • observe and identify daily weather conditions — sunny, rainy, cloudy, snowy, windy, warm, hot, cool, and cold. • predict daily weather based on basic observable conditions. • chart daily weather conditions. • identify simple patterns in natural objects — veins in a leaf, spiral patterns in cones, shapes and colors of common seeds. • ~~identify and describe patterns in their daily schedule at home.~~ • ~~identify and describe patterns in their daily schedule at school.~~ • ~~distinguish between the patterns in home activities and those in school activities.~~ • describe how animals and plants change as they grow. (Related to ~~K.6~~ K.7.)

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

~~Understanding the Standard~~ Overview

Almost everything changes over time. Those changes can be observed and measured. Standard ~~K.9~~ K.10 focuses on student understanding of the basic aspects of change, especially in those things that can be easily observed and are within the experience of kindergarten children. Change is a key concept woven into most of the science standards throughout elementary, middle, and high school. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

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

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Change occurs over time. • Change can be fast or slow depending upon the object and conditions. • As people grow, they change. • Not all things change at a rate that can be observed easily. • Many changes can be measured.	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify some changes that people experience over time — e.g., height, weight, and color of hair. • predict how their own height ~~and weight~~ will change over the school year. Measure and graph the information. • describe how people cause things to change — e.g., demolition of buildings, construction of buildings, cutting down trees, planting trees, and building highways. • describe how things change naturally. This includes seasonal changes, the growth in seeds and common plants, common animals, ~~including the butterfly,~~ and the weather. • identify examples of fast changes and slow changes. Slow changes should be the kinds of familiar changes that occur over weeks, months, or seasons. (Students are not responsible for long-term changes.)

Earth Resources

This strand focuses on student understanding of the role of natural resources and how people can utilize those resources in a sustainable way. Resource management is an important idea developed within the strand. This begins with basic ideas of conservation and proceeds in the sixth grade to the more abstract consideration of costs and benefits. The topics developed include the conservation of household materials, the importance of soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards ~~K.10,~~ K.11, 1.8, 2.8, 3.10, 3.11, ~~4.8,~~ 4.9, and 6.9.

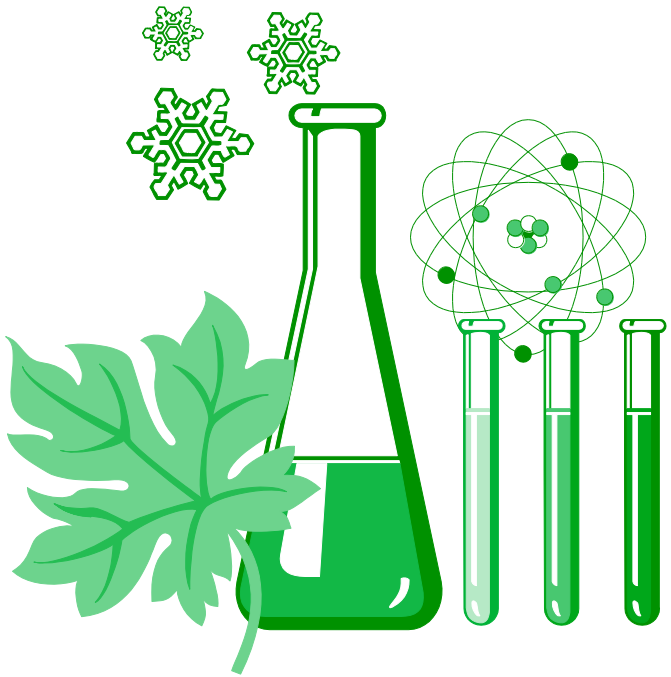
K.11	The student will investigate and understand that materials can be reused, recycled, and conserved. Key concepts include a) materials and objects can be used over and over again; b) everyday materials can be recycled; and c) water and energy conservation at home and in school helps ensure resources are available for future use.

~~Understanding the Standard~~ Overview

Standard ~~K.10~~ K.11 focuses on student understanding that materials can be reused, recycled, and conserved. This should include common objects and materials found in the school and home environment. ~~K.10~~ K.11 establishes a foundation for increasingly advanced conservation concepts developed in the primary standards. Note that science standard 1.8 is very closely related to ~~K.10~~ K.11. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

K.11 The student will investigate and understand that materials can be reused, recycled, and conserved. Key concepts include
a) materials and objects can be used over and over again;
b) everyday materials can be recycled; and
c) water and energy conservation at home and in school helps ensure resources are available for future use.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Natural resources such as water and energy should be conserved. • Recycling helps to save our natural resources. Recycling recovers used materials. Many materials can be recycled and used again, sometimes in different forms. Examples include newspapers that are turned into writing tablets. • Reusing materials means using them more than once. Examples include using dishes and utensils that are washed after use rather than using paper plates and plastic utensils and putting them in the trash. • Recycling, reusing, and conserving helps preserve resources for future use. • Resources will last longer if we recycle, reuse, and reduce consumption.	In order to meet this standard, it is expected that students ~~should be able to~~ will • give examples of objects, such as paper, plastic containers, and glass containers, that can be recycled. • identify materials that can be reused. • describe the difference between recycle and reuse. • name ways to conserve water and energy. • describe how to ~~recycle~~ properly dispose of a given material — paper, oil, aluminum, glass and plastics — by recycling. • predict what would happen if recycling and reusing were not practiced.



Science Standards of Learning Curriculum Framework

Grade One

Final Review
November 18, 2010

Commonwealth of Virginia
Board of Education
Richmond, Virginia
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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Grade One
Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student ~~should~~ will be able to do when conducting activities and investigations, and represents the student understanding of the nature of science. The various skill categories are described in the "Investigate and Understand" section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 1.1 represent more specifically what a student should achieve during the course of instruction in the first grade. Across the grade levels, the skills in the first standards form a nearly continuous sequence of investigative skills and an understanding of the nature of science. ~~(Please note Appendix, "Science Skills, Scope, & Sequence").~~ It is important that the classroom teacher understand~~s~~ how the skills in standard 1.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). ~~It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in the "Scientific Investigation, Reasoning, and Logic" strand.~~

1.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) the senses are used to observe differences in physical properties;
b) observations are made from multiple positions to achieve a variety of perspectives and are repeated to ensure accuracy;
c) objects or events are classified and arranged according to characteristics or properties;
d) simple tools are used to enhance observations;
e) length, mass, volume, and temperature are measured using nonstandard units;
f) inferences are made and conclusions are drawn about familiar objects and events;
g) a question is developed from one or more observations;
h) predictions are made based on patterns of observations;
i) observations and data are recorded, analyzed, and communicated orally and with simple graphs, pictures, written statements, and numbers; and
j) simple investigations and experiments are conducted to answer questions.

~~Understanding the Standard~~ Overview

~~The skills described in s~~Standard 1.1 ~~are~~ is intended to define the "investigate" component of all other first-grade standards (1.2–1.8). The intent of standard 1.1 is that students will continue to develop a range of inquiry skills, ~~and~~ achieve proficiency with those skills, and continue to develop an understanding of the nature of science in the context of the concepts developed ~~at the~~ in first grade. **Standard 1.1 does not require a discrete unit be taught on scientific investigation because the ~~inquiry~~ skills that make up the standard should be incorporated in all other first-grade standards.** It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science as well as more fully grasp the content-related SOL concepts.

1.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) the senses are used to observe differences in physical properties;
b) observations are made from multiple positions to achieve a variety of perspectives and are repeated to ensure accuracy;
c) objects or events are classified and arranged according to characteristics or properties;
d) simple tools are used to enhance observations;
e) length, mass, volume, and temperature are measured using nonstandard units;
f) inferences are made and conclusions are drawn about familiar objects and events;
g) a question is developed from one or more observations;
h) predictions are made based on patterns of observations;
i) observations and data are recorded, analyzed, and communicated orally and with simple graphs, pictures, written statements, and numbers; and
j) simple investigations and experiments are conducted to answer questions.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts: a) the natural world is understandable; b) science is based on evidence, both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. In grade one, an emphasis should be placed on concepts a, b, and e. • Science assumes that the natural world is understandable. Scientific inquiry can provide explanations about nature. This expands students' ~~knowledge~~ thinking from just a knowledge of facts to understanding ~~why~~ how ~~the~~ facts are relevant to everyday life.	In order to meet this standard, it is expected that students ~~should be able to~~ will • use their senses and simple tools, such as a magnifying glass~~, ruler, and thermometer,~~ and a balance to enhance their observations of physical properties. • make repeated observations of an object or event from multiple positions. • classify and arrange objects or events according to at least two attributes or properties so that similarities and differences become apparent. • measure length, mass, and volume, using ~~standard and~~ nonstandard units~~ and appropriate instruments~~. ~~By the third grade, students will be expected to have basic facility with metric measures, including centimeters, grams, and liters.~~ • use familiar events and objects to make inferences and draw conclusions.

1.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) the senses are used to observe differences in physical properties;
b) observations are made from multiple positions to achieve a variety of perspectives and are repeated to ensure accuracy;
c) objects or events are classified and arranged according to characteristics or properties;
d) simple tools are used to enhance observations;
e) length, mass, volume, and temperature are measured using nonstandard units;
f) inferences are made and conclusions are drawn about familiar objects and events;
g) a question is developed from one or more observations;
h) predictions are made based on patterns of observations;
i) observations and data are recorded, analyzed, and communicated orally and with simple graphs, pictures, written statements, and numbers; and
j) simple investigations and experiments are conducted to answer questions.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• Science demands evidence. Scientists develop their ideas based on evidence and they change their ideas when new evidence becomes available or the old evidence is viewed in a different way. • Science is a complex social endeavor. It is a complex social process for producing knowledge about the natural world. Scientific knowledge represents the current consensus as to what is the best explanation for phenomena in the natural world. This consensus does not arise automatically, since scientists with different backgrounds from all over the world may interpret the same data differently. To build a consensus, scientists communicate their findings to other scientists and attempt to replicate one another's findings. In order to model the work of professional scientists, it is essential for first-grade students to engage in frequent discussions with peers about their understanding of their investigations. • To communicate an observation accurately, one must provide a clear description of exactly what is observed and nothing more. • Observations should be made from multiple positions (e.g., observations of the same object from the front of the object, from the back of the object, looking down on the object, etc.) whenever possible to achieve a variety of perspectives.	• develop a question from one or more observations. • predict outcomes based on actual observations and evidence rather than random guesses. • communicate observations ~~made~~ and data ~~collected orally and~~ with simple graphs~~,~~ and pictures, oral and written statements, and with numbers. • answer questions by conducting simple experiments/investigations, using nonstandard measuring units and simple tools, such as ~~thermometer, ruler, or~~ a magnifying glass or ~~nonstandard measuring units~~ a balance. A simple experiment is one that changes only one thing at a time (tests only one variable), gives quick results, and provides easily observable changes. • record observations of movement (length/distance)~~,~~ using ~~standard (English/metric) and~~ nonstandard units. • compare the movement of objects, using graphs, pictures, and/or numbers.

1.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) the senses are used to observe differences in physical properties;
b) observations are made from multiple positions to achieve a variety of perspectives and are repeated to ensure accuracy;
c) objects or events are classified and arranged according to characteristics or properties;
d) simple tools are used to enhance observations;
e) length, mass, volume, and temperature are measured using nonstandard units;
f) inferences are made and conclusions are drawn about familiar objects and events;
g) a question is developed from one or more observations;
h) predictions are made based on patterns of observations;
i) observations and data are recorded, analyzed, and communicated orally and with simple graphs, pictures, written statements, and numbers; and
j) simple investigations and experiments are conducted to answer questions.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• Observations should be repeated multiple times to assure accuracy. • Once the characteristics of several objects or several events have been observed and recorded, the objects or events can be arranged by those characteristics (e.g., several objects sorted by color, several events sorted on a timeline by age, etc.). • Simple tools, such as a magnifying glass~~, ruler, and thermometer~~ and a balance~~,~~ can extend the observations that people can make. • ~~Standard measures are important for describing an object because standard measures are recognized by everyone. Many nonstandard measures, such as hand or finger length, vary considerably.~~ Nonstandard units such as paper clips, a student's foot, index cards, etc., can be used to measure the length of objects. The mass of two objects can be compared by holding each object in a different hand. The volume of various liquids can be compared by pouring them in cups of the same size. Variations in temperature of different objects can be compared by the difference that is felt when each object is touched. Variations in air temperature can be compared by observing the differences one feels when in different environments (e.g., inside the classroom vs. outside on the playground in winter, inside the freezer compartment of a refrigerator vs. inside a kitchen).	

1.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) the senses are used to observe differences in physical properties;
b) observations are made from multiple positions to achieve a variety of perspectives and are repeated to ensure accuracy;
c) objects or events are classified and arranged according to characteristics or properties;
d) simple tools are used to enhance observations;
e) length, mass, volume, and temperature are measured using nonstandard units;
f) inferences are made and conclusions are drawn about familiar objects and events;
g) a question is developed from one or more observations;
h) predictions are made based on patterns of observations;
i) observations and data are recorded, analyzed, and communicated orally and with simple graphs, pictures, written statements, and numbers; and
j) simple investigations and experiments are conducted to answer questions.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• An inference is a ~~conclusion based on evidence about events that have already occurred~~ tentative explanation based on background knowledge and available data. • A conclusion is a summary statement based on data from the results of an investigation. • Questions about what is observed can be developed. • A prediction is a forecast about what may happen in some future situation. It is based on information and evidence. A prediction is different from a guess. • Graphs are powerful ways to display data, making it easier to recognize important information. Describing things as accurately as possible is important in science because it enables people to compare their observations with those of others. • Data should be displayed in bar graphs and picture graphs at the grade one level. • An experiment is a fair test designed to answer a question.	

Grade One
Science Strand

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

1.2	The student will investigate and understand that moving objects exhibit different kinds of motion. Key concepts include a) objects may have straight, circular, and back-and-forth motions; b) objects may vibrate and produce sound; and c) pushes or pulls can change the movement of an object.

~~Understanding the Standard~~ Overview

Physical science includes topics that give students a chance to increase their understanding of the characteristics of objects and materials that they encounter daily. Knowledge about objects develops through learning how they move and change position and shape in relation to the viewer, as when we look at objects from different angles. Students learn about objects by observing them and noting similarities and differences and by acting on them by applying force. This concept relates to science standard K.3, in which magnets push and pull objects. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

1.2 The student will investigate and understand that moving objects exhibit different kinds of motion. Key concepts include
a) objects may have straight, circular, and back-and-forth motions;
b) objects may vibrate and produce sound; and
c) pushes or pulls can change the movement of an object.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • An object's motion may be described by tracing and measuring its position over time. The motion of objects may be straight, circular, curved, or back-and-forth. • One kind of back-and-forth motion is vibration. Vibrations may create sound. • Pushing or pulling can change the position and motion of objects. For the same object, the size of the change is related to the strength of the push or pull.	In order to meet this standard, it is expected that students ~~should be able to~~ will • make and communicate observations about moving objects. Examples should include balls, objects with wheels, windup toys, tops, rubber bands, and playground equipment. • predict an object's movement, using its size, shape, and the force of the push or pull on it. • ~~conduct a simple experiment to determine an object's movement.~~ • manipulate objects in order to describe and classify the motion of ~~an~~ each object as straight, circular, ~~curved,~~ or back-and-forth. • understand that vibrations may create sound, such as humming, strumming a guitar, or plucking a rubber band. • record observations of movement (length/distance), using ~~standard (English/metric) and~~ nonstandard units. • ~~compare the movement of objects, using graphs, pictures, and/or numbers.~~

Grade One
Science Strand

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, ~~states~~ phases of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure of classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

1.3	The student will investigate and understand how different common materials interact with water. Key concepts include a) some liquids will separate when mixed with water, but others will not; b) some solids will dissolve in water, but others will not; and c) some substances will dissolve more readily in hot water than in cold water.

~~Understanding the Standard~~ Overview

Students continue their study of water by examining and qualitatively describing water and its behavior with other matter. When carefully observed, described, and measured, the properties of objects in or with water, and the changes that occur when materials interact with water, provide the necessary foundation for more abstract ideas in the upper grade levels. This concept is related to science standard K.5 in which students identify water in its different ~~states~~ phases (solid, liquid, gas). It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

1.3	The student will investigate and understand how different common materials interact with water. Key concepts include a) some liquids will separate when mixed with water, but others will not; b) some solids will dissolve in water, but others will not; and c) some substances will dissolve more readily in hot water than in cold water.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Different types of materials ~~react~~ act differently when mixed with water. • Some liquids will mix with water, while others will not. • Some solids will dissolve in water, while others will not. • The temperature of the water affects how easily a substance will dissolve in it.	In order to meet this standard, it is expected that students ~~should be able to~~ will • describe and apply the term dissolve. • predict and describe how various materials (vinegar, milk, baking soda, powdered drink mix, sugar, salt, sand, oil, soil, rocks) act when mixed with water. • classify liquids and solids into those that will dissolve in water and those that will not. Use ~~picture graphs,~~ tables~~,~~ and/or charts to record and display the information. • infer that some substances will dissolve more easily in hot water than in cold water by conducting investigations using water at different temperatures.

Grade One
Science Strand

Life Processes

This strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards K.6, K.7, 1.4, 1.5, 2.4, 3.4, and 4.4.

1.4	The student will investigate and understand that plants have basic life needs and functional parts and can be classified according to certain characteristics. Key concepts include a) plants need nutrients, air, water, light, and a place to grow; b) basic parts of plants; and c) plants can be classified based on a variety of characteristics.

~~Understanding the Standard~~ Overview

Young children have a natural curiosity about the living things that they encounter. Observation is a method by which students can answer questions about how plants live, their parts, and characteristics. All plants need ~~nourishment~~ nutrients, air, water, light, and a place with sufficient space to grow. They have specific structures to meet their needs. Students need to know the concepts, not the definitions, of the terms edible, nonedible, evergreen, and deciduous. They need to know that we eat certain plants (edible) but not others (nonedible). They need to know that some plants stay green all year long (evergreen) while others lose their leaves each fall (deciduous). The concepts in this standard build upon the Life Processes strand (K.6 and K.7), in which students investigate and understand basic needs and life processes of plants and animals. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

1.4	The student will investigate and understand that plants have basic life needs and functional parts and can be classified according to certain characteristics. Key concepts include a) plants need nutrients, air, water, light, and a place to grow; b) basic parts of plants; and c) plants can be classified based on a variety of characteristics.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Plants have basic needs, including ~~food~~ nutrients, air, water, light, and a place with sufficient space to grow. • Plants have different structures that serve different functions in growth, survival, and reproduction. • The functions of plant parts include the roots which hold~~ing~~ plants in place and absorb~~ing~~ water, seeds which ~~making~~ make new plants, leaves which ~~making~~ make food for the plant, and stems which hold~~ing~~ the plants upright and transport~~ing~~ materials up and down the plant. • Plants can be categorized by their different characteristics, such as edible/nonedible, flowering/nonflowering, and evergreen/deciduous. **Students do not need to know the terms nonedible, edible, evergreen, and deciduous. The focus should be on the concept, not the terminology.**	In order to meet this standard, it is expected that students ~~should be able to~~ will • conduct simple experiments/investigations related to plant needs by changing one variable (~~food~~ nutrients, air, water, light, or place to grow) at a time. **Students do not need to know the term variable**. • create and interpret a model/drawing of a plant, including seeds, roots, stems, leaves, ~~blossoms~~ flowers, and fruits. • identify the functions of the seed, root, stem, and leaf. • classify plants by the characteristics of edible/nonedible, flowering/nonflowering, and evergreen/deciduous, using ~~tables,~~ charts~~, and picture graphs~~.

1.5	The student will investigate and understand that animals, including humans, have basic needs and certain distinguishing characteristics. Key concepts include a) basic needs include adequate air, food, water, shelter, and space (habitat); b) animals, including humans, have many different physical characteristics; and c) animals can be classified according to a variety of characteristics.

~~Understanding the Standard~~ Overview

This standard focuses on the idea that animals move, need food, breathe, and reproduce. Animals have a variety of ways in which they accomplish these activities. Each type of animal has features that allow it to function in unique and specific ways to obtain food, reproduce, and survive in a particular place. This standard builds upon the Life Processes strand (K.6 and K.7), in which students are introduced to the concept of living and nonliving, and investigate and understand basic needs and life processes of plants and animals. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

1.5 The student will investigate and understand that animals, including humans, have basic needs and certain distinguishing characteristics. Key concepts include

a) basic needs include adequate air, food, water, shelter, and space (habitat);
b) animals, including humans, have many different physical characteristics; and
c) animals can be classified according to a variety of characteristics.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Animals, including people, have basic life needs, including air, food, water, ~~and a suitable place to live~~ shelter, and space (habitat). **Students do not need to know the term habitat. The focus should be on the items that are necessary components of a habitat, not on the terminology.** • Body coverings include hair, fur, feathers, scales, and shells. • Appendages are parts, such as arms, legs, wings, fins, and tails, ~~that~~ which extend from the main body and ~~that~~ have specific functions. **Students do not need to know the term appendage. The focus should be on the concept, not the terminology.** • Methods of movement may include walking, crawling, flying, and swimming. • Simple ways to classify animals are whether they are wild or ~~tame~~ domestic and whether they live on land or in water.	In order to meet this standard, it is expected that students ~~should be able to~~ will • make and communicate observations of live animals, including ~~people~~ humans, about their needs, physical characteristics, and where they live. • describe the life needs of animals, including air, food, water, ~~and a suitable place to live~~ shelter, and space. • identify and chart simple characteristics by which animals can be classified, including body coverings (hair, fur, feathers, scales, and shells), body shape, appendages (arms, legs, wings, fins, and tails), methods of movement (walking, crawling, flying, and swimming), wild or ~~tame~~ domestic, and water homes or land homes. • distinguish between wild animals (raccoon, hawk, squirrel, shark) and ~~tame~~ domestic animals (dog, cat, sheep) and recognize examples of each. • infer types of animal homes (water or land), using the physical characteristics of the animals, such as scales and fins that allow fish to live and move in water or fur and legs that allow dogs to live and move on land. • classify animals by where they live (their homes).

Grade One
Science Strand

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of relationships within and among Earth and space systems. The topics developed include shadows; relationships between the sun and the Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards ~~K.7~~ K.8, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

1.6	The student will investigate and understand the basic relationships between the sun and Earth. Key concepts include a) the sun is the source of energy and light that warms the land, air, and water; and b) the sun's relative position in the morning is east and in the late afternoon is west.

~~Understanding the Standard~~ Overview

This standard focuses on some of the important relationships between the sun and ~~the~~ Earth. ~~Day and night occur because Earth turns or rotates on its axis. Earth turns on its axis once a day. Students need to understand the concepts of rotation and axis, but they do not need to know the terms.~~ Students need to understand that the sun is a source of energy, and that energy provides light and warmth for Earth. This standard builds upon science standard ~~K.7~~ K.8 about light and shadow. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

1.6 The student will investigate and understand the basic relationships between the sun and Earth. Key concepts include
a) the sun is the source of energy and light that warms the land, air, and water; and
b) the sun's relative position in the morning is east and in the late afternoon is west.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • The sun ~~is~~ provides Earth ~~the a source of~~ with light (a form of radiant energy) and ~~heat~~ thermal energy ~~on Earth~~. • By transferring thermal energy to Earth, Earth's atmosphere and land are heated. ~~Heat is a form of energy.~~ ~~Heat~~ Thermal energy may be transferred from one substance to another by three means: conduction, convection, and radiation. • The sun provides ~~heat~~ energy, which warms the land, air, and water on Earth. • ~~The rotation of Earth means that Earth turns once a day. The part of Earth facing the sun has daytime and the part not facing the sun has nighttime.~~ • ~~Rotation of the Earth causes day and night.~~ • The sun's relative position in the morning is east and in the late afternoon is west.	In order to meet this standard, it is expected that students ~~should be able to~~ will • infer that sunlight striking an object makes the object warmer. • conduct simple experiments to show how sunlight changes the temperature of land, air, and water. • ~~demonstrate and describe the concept of rotation.~~ • ~~comprehend that day and night are caused by Earth's rotation.~~ • ~~compare and contrast day and night by characteristic changes in temperature and light.~~ • ~~model the rotation of Earth and its physical relationship to the sun.~~ • interpret the relationship between the sun's position in the sky and the general time of day. This includes the sun's relative position in the morning (east), at noon, and in the late afternoon (west).

Grade One
Science Strand

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living things. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, our solar system, and change in ~~the~~ Earth's surface over time. This strand includes science standards ~~K.8,~~ K.9, K.10 1.7, 2.7, 3.8, 3.9, 4.7, and 5.7.

1.7	The student will investigate and understand weather and seasonal changes. Key concepts include a) changes in temperature, light, and precipitation affect plants and animals, including humans; b) there are relationships between daily and seasonal changes; and c) changes in temperature, light, and precipitation can be observed and recorded over time.

~~Understanding the Standard~~ Overview

The focus of this standard is on temperature, light, and precipitation as they relate to life changes in plants, animals, and people. There are many ways to acquaint children with Earth science-related phenomena that they will come to understand later as being cyclic, and this standard introduces those ideas. It is enough for young children to observe the pattern of daily changes without getting deeply into the nature of climate. They should notice how these changes affect plants and animals. This is observable and can be charted over short and intermediate time periods. Students need to understand the concepts of migration, hibernation, and habitat, but they do not necessarily need to know the terms at first grade. This standard builds upon science standard ~~K.8~~ K.9 in which students investigate and understand simple patterns in their daily lives. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

1.7 The student will investigate and understand weather and seasonal changes. Key concepts include
a) changes in temperature, light, and precipitation affect plants and animals, including humans;
b) there are relationships between daily and seasonal changes; and
c) changes in temperature, light, and precipitation can be observed and recorded over time.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Seasonal changes bring about changes in plants, animals, and people. • With seasonal changes come changes in weather, including temperature, light, and precipitation. • Precipitation includes rain, snow, and ice. • Changes in plants include budding, growth, ~~wilting,~~ and losing leaves. • Some animals hibernate and some animals migrate as a result of seasonal changes, resulting in changes in habitat. **Students do not need to know the terms migration, hibernation, and habitat. The focus should be on the concepts, not the terminology.** • Hibernation is a state of greatly reduced metabolic activity and lowered body temperature adopted by certain mammals as an adaptation to adverse winter conditions. Most animals are not "true hibernators" but rely on a combination of reserve body fat, stored food supplies (in rodents only), and a protected den to enable it to survive the winter. At intervals of several weeks the animal elevates its body temperature, awakens, moves about, feeds, and then returns to its state of torpor. • Migration is the regular, usually seasonal, movement of all or part of an animal population to and from a given area. The distance traveled may be a few miles or several thousands of miles. Animals migrate for many different reasons. Some animals migrate to find better sources of food, water, or shelter. Other animals migrate to visit particular breeding grounds, rear their young, or find warmer climates. The frequency of animals' migrations also differs. • An animal's living place is called its habitat. Most animals are only adapted to live in one or two habitats. Earth has many different	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify types of precipitation as rain, snow, and ice and the temperature conditions that result in each one. • relate a temperature, light, and precipitation chart to the corresponding season (daily or weekly). • ~~measure~~ observe and chart changes in plants, including budding, growth, ~~wilting,~~ and losing leaves. Recognize in what season budding and ~~wilting~~ losing leaves will most likely occur. • predict how an outdoor plant would change through the seasons. • compare and contrast the four seasons of spring, summer, fall (autumn) and winter in terms of temperature, light, and precipitation. • compare and contrast the activities of some common animals (e.g., squirrels, chipmunks, butterflies, bees, ants, bats, ~~and~~ frogs, and humans) during summer and winter by describing changes in their behaviors and body covering. • compare and contrast how some common plants (e.g., oak trees, pine trees, and lawn grass) appear during summer and winter. • comprehend at an introductory level that some animals respond to seasonal changes by hibernating (e.g., frogs, bats) or migrating (e.g., some birds and butterflies) ~~the concepts of hibernation, migration, and habitat, and describe how these relate to seasonal changes~~. (It may be useful to recognize common Virginia animals that hibernate and migrate, but the specific names of animals is not the focus of student learning here.)

1.7 The student will investigate and understand weather and seasonal changes. Key concepts include a) changes in temperature, light, and precipitation affect plants and animals, including humans; b) there are relationships between daily and seasonal changes; and c) changes in temperature, light, and precipitation can be observed and recorded over time.	
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
environments, varying in temperature, moisture, light, and many other factors. Each of these habitats has distinct life forms living in it, forming complex communities of interdependent organisms. A habitat must include a source of food for the animal, a source of water for the animal, access to some sort of shelter for the animal, and an adequate amount of space so that enough habitat components are available to the animal. Some animals' habitats are very small, but some animals require a large amount of space. • The body coverings of some animals change with the seasons. This includes thickness of fur and coloration. • Changes ~~in~~ made by people include their dress, recreation, and work.	• infer what the season is from people's dress, recreational activities, and work activities.

Grade One
Science Strand

Earth Resources

This strand focuses on student understanding of the role of resources in the natural world and how people can utilize those resources in a sustainable way. An important idea represented in this strand is the concept of management of resource use. This begins with basic ideas of conservation and proceeds to more abstract consideration of costs and benefits. The topics developed include conservation of materials, soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards ~~K.10~~ K.11, 1.8, 2.8, 3.10, 3.11, ~~4.8~~ 4.9, and 6.9.

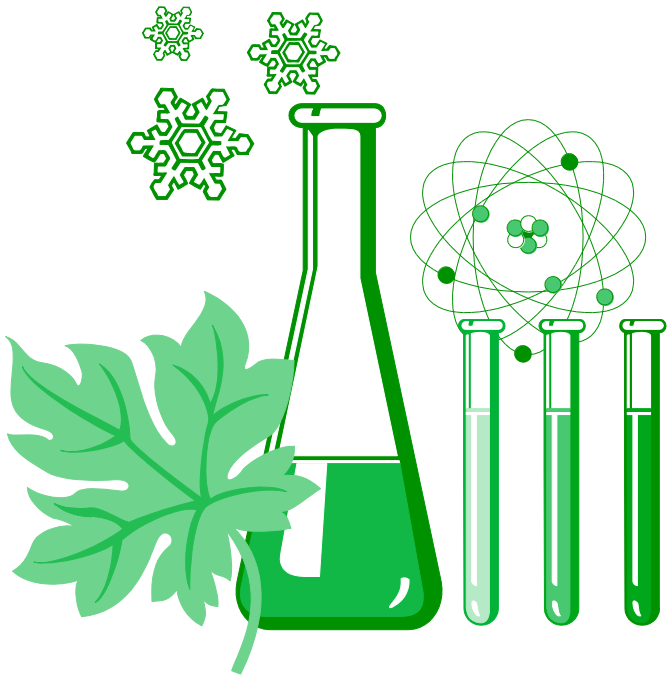
1.8	The student will investigate and understand that natural resources are limited. Key concepts include a) identification of natural resources; b) factors that affect air and water quality; and c) recycling, reusing, and reducing consumption of natural resources.

~~Understanding the Standard~~ Overview

This standard focuses on identifying what natural resources are; basic ways we can help conserve those natural resources, especially water and air; and the preservation of land to use as parks. The standard extends the perception of young students from the present to the future and from self to their community. Standard ~~K.10~~ K.11 establishes a foundation for this standard. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

1.8 The student will investigate and understand that natural resources are limited. Key concepts include
a) identification of natural resources;
b) factors that affect air and water quality; and
c) recycling, reusing, and reducing consumption of natural resources.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Natural resources provide us with the things we need in order to live, including food, clothing, water, air, shelter, land, and energy. • What we put into the air, especially the products of the fuels we burn, affects the quality of the air. Waste produced by ~~A~~animals, including humans, and factor~~y~~ies ~~wastes~~ can affect the quality of water. Some pollution washes from yards, streets, and farms. • Many natural resources are limited and cannot be renewed. Other resources are limited and cannot be renewed, but they may last a very long time. • Recycling recovers used materials. Many materials can by recycled and used again, sometimes in different forms. Recycling helps to save our natural resources. An example of a recycled material is newspapers that are turned into writing tablets. • Reusing materials means using them more than once. Examples include using dishes and utensils that are washed after use rather than using paper plates and plastic utensils and putting them in the trash. • Resources will last longer if we recycle them, reuse them, or reduce consumption of them. • The creation of parks can help preserve land. Parks have many uses, including recreation.	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify natural resources such as plants and animals, water, air, land, minerals, forests, and soil. • recognize that many natural resources are limited. • compare and contrast ways of conserving resources. This includes recycling, reusing, and reducing consumption of natural resources. • classify factors that affect air and water quality. • describe ways students and schools can help improve water and air quality in our communities. • determine some basic factors that affect water quality by conducting simple investigations in the school environment. Students should be able to make and record observations of what happens to runoff water on rainy days. (Related to 1.3.) • predict what would happen if natural resources were used up, and explain ways to prevent this from happening. • discuss the value of parks to wildlife and to people.



Science Standards of Learning Curriculum Framework

Grade Two

Final Review
November 18, 2010

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Board of Education
Richmond, Virginia
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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Grade Two
Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student ~~should~~ will be able to do when conducting activities and investigations, and represents the student understanding of the nature of science. The various skill categories are described in the "Investigate and Understand" section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 2.1 represent more specifically what a student should achieve during the course of instruction in the second grade. Across the grade levels, the skills in the first standards form a nearly continuous sequence of investigative skills and an understanding of the nature of science. ~~(Please note Appendix, "Science Skills, Scope, & Sequence.").~~ It is very important that the second grade classroom teacher be familiar with the skills in the sequence leading up to standard 2.1. For example in K.1 and in 1.1, nonstandard units are used to measure common objects~~, and in 1.1, standard and nonstandard units are used~~. In grade two, 2.1 specifies metric and English units of measure. A second-grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed. ~~It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in the "Scientific Investigation, Reasoning, and Logic" strand.~~

2.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) observations and predictions are made and questions are formed; b) observations are differentiated from personal interpretation; c) observations are repeated to ensure accuracy; d) two or more characteristics or properties are used to classify items; e) length, volume, mass, and temperature are measured in metric units and standard English units using the proper tools; f) time is measured using the proper tools; g) conditions that influence a change are identified and inferences are made; h) data are collected and recorded, and bar graphs are constructed using numbered axes; i) data are analyzed, and unexpected or unusual quantitative data are recognized; j) conclusions are drawn; k) observations and data are communicated; l) simple physical models are designed and constructed to clarify explanations and show relationships; and m) current applications are used to reinforce science concepts.

~~Understanding the Standard~~ Overview

~~The skills defined in s~~Standard 2.1 ~~are~~ is intended to ~~define the "investigate" to~~ develop investigative and inquiry ~~component~~ skills and the understanding of the nature of science ~~of~~ for all of the other second-grade standards. Standard 2.1 requires students to continue developing a range of inquiry skills and achieve proficiency with those skills, and develop and reinforce their understanding of the nature of science in the context of the concepts developed ~~at the~~ in second grade. **Standard 2.1 does not require a discrete unit be taught on scientific investigation and the nature of science because the ~~inquiry~~ skills that make up the standard should be incorporated in all the other second grade standards.** It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science as well as more fully grasp the content-related concepts.

2.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) observations and predictions are made and questions are formed;
b) observations are differentiated from personal interpretation;
c) observations are repeated to ensure accuracy;
d) two or more characteristics or properties are used to classify items;
e) length, volume, mass, and temperature are measured in metric units and standard English units using the proper tools;
f) time is measured using the proper tools;
g) conditions that influence a change are identified and inferences are made;
h) data are collected and recorded, and bar graphs are constructed using numbered axes;
i) data are analyzed, and unexpected or unusual quantitative data are recognized;
j) conclusions are drawn;
k) observations and data are communicated;
l) simple physical models are designed and constructed to clarify explanations and show relationships; and
m) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts: a) the natural world is understandable; b) science is based on evidence, both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. In grade two, an emphasis should be placed on concepts a, b, and e. • Science assumes that the natural world is understandable. Scientific inquiry can provide explanations about nature. This expands students' ~~knowledge~~ thinking from just a knowledge of facts to understanding	In order to meet this standard, it is expected that students ~~should be able to~~ will • conduct simple experiments, make predictions, gather data from those experiments, repeat observations to improve accuracy, and draw conclusions. • differentiate among simple observations and personal interpretations. ~~This requires students to comprehend what an observation is and apply the term in novel situations related to second-grade SOL concepts.~~ • classify items, using two or more attributes such as size, shape, color, texture, and weight. • use centimeters, meters, liters, degrees Celsius, grams, and kilograms in measurement. • use inches, feet, yards, quarts, gallons, degrees Fahrenheit, ounces, and pounds in measurement. • measure time using both digital and analog clocks.

2.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) observations and predictions are made and questions are formed;
b) observations are differentiated from personal interpretation;
c) observations are repeated to ensure accuracy;
d) two or more characteristics or properties are used to classify items;
e) length, volume, mass, and temperature are measured in metric units and standard English units using the proper tools;
f) time is measured using the proper tools;
g) conditions that influence a change are identified and inferences are made;
h) data are collected and recorded, and bar graphs are constructed using numbered axes;
i) data are analyzed, and unexpected or unusual quantitative data are recognized;
j) conclusions are drawn;
k) observations and data are communicated;
l) simple physical models are designed and constructed to clarify explanations and show relationships; and
m) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~why~~ how ~~the~~ facts are relevant to everyday life. • Science demands evidence. Scientists develop their ideas based on evidence and they change their ideas when new evidence becomes available or the old evidence is viewed in a different way. • Science is a complex social endeavor. It is a complex social process for producing knowledge about the natural world. Scientific knowledge represents the current consensus as to what is the best explanation for phenomena in the natural world. This consensus does not arise automatically, since scientists with different backgrounds from all over the world may interpret the same data differently. To build a consensus, scientists communicate their findings to other scientists and attempt to replicate one another's findings. In order to model the work of professional scientists, it is essential for second-grade students to engage in frequent discussions with peers about their understanding of their investigations. • In order to communicate accurately, it is necessary to provide a clear description of exactly what is observed. There is a difference between what one can observe and what can be interpreted from an observation.	• identify conditions that influence a change in an experiment. • construct and interpret simple models (~~for example~~ e.g., weathering and erosion of land surfaces — 2.7). • analyze sets of objects, numerical data, or pictures, and create basic categories to organize the data (descriptive or numerical). • judge which, if any, collected data in a small set appear to be unexpected or unusual. • construct and interpret picture and bar graphs with numbered axes depicting the distribution of data. • communicate observations and data.

2.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) observations and predictions are made and questions are formed;
b) observations are differentiated from personal interpretation;
c) observations are repeated to ensure accuracy;
d) two or more characteristics or properties are used to classify items;
e) length, volume, mass, and temperature are measured in metric units and standard English units using the proper tools;
f) time is measured using the proper tools;
g) conditions that influence a change are identified and inferences are made;
h) data are collected and recorded, and bar graphs are constructed using numbered axes;
i) data are analyzed, and unexpected or unusual quantitative data are recognized;
j) conclusions are drawn;
k) observations and data are communicated;
l) simple physical models are designed and constructed to clarify explanations and show relationships; and
m) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• An observation is what you actually see, feel, taste, hear, or smell. • The more times an observation is repeated, the greater the chance of ensuring the accuracy of the observation. • It is easier to see how things are related if objects are classified according to their common characteristics. • By constructing and studying simple models, it is sometimes easier to understand how real things work. • Scientific investigations require standard measures, ~~reliable~~ proper tools (e.g., balance scale, thermometer, ruler, magnifying glasses), and organized collection and reporting of data. The way the data are displayed can make it easier to interpret important information. • When using any standard measurement scale, measure to the marked increment and estimate one more decimal place. Scientists do not round their measurements as this would be inaccurate. • Students should communicate observations and data publicly.	

Grade Two
Science Strand

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

2.2	The student will investigate and understand that natural and artificial magnets have certain characteristics and attract specific types of metals. Key concepts include a) magnetism, iron, magnetic/nonmagnetic, poles, attract/repel; and b) important applications of magnetism.

~~Understanding the Standard~~ Overview

This standard continues the focus on magnets. In K.3 students investigate and learn that magnets can be used to make some things move without touching them by either attracting them or repelling them. In 2.2, the study of magnets ~~are revisited~~ is expanded ~~and~~ as students investigate and understand that magnets can be artificial or natural and have certain characteristics. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

2.2 The student will investigate and understand that natural and artificial magnets have certain characteristics and attract specific types of metals. Key concepts include
a) magnetism, iron, magnetic/nonmagnetic, poles, attract/repel; and
b) important applications of magnetism.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Magnets have a north and a south pole. • Unlike magnetic poles attract~~,~~ and like poles repel. The north pole of one magnet attracts the south pole of a second magnet, while the north pole of one magnet repels the other magnet's north pole. • A magnet creates an invisible area of magnetism all around it called a magnetic field. • The north ~~pole~~ end of a magnetic compass always points roughly toward Earth's North Pole and ~~vice-versa~~ the south end of the compass needle always points toward Earth's South Pole. That is because Earth itself contains magnetic materials and behaves like a gigantic magnet. • When a magnetized metal, such as a compass needle, is allowed to swing freely, it displays the interesting property of aligning with the Earth's magnetic fields. • A magnet is strongest at its poles. • The farther away the magnetic poles are from each other, the weaker the magnetic force. • If you cut a bar magnet in half, you get two new, smaller magnets, each with its own north and south pole. • Magnets can attract objects made of iron, ~~or~~ nickel, or cobalt. • Magnets can be artificially made from special metals or can occur naturally. Naturally occurring magnets are composed of a mineral called magnetite ~~(~~ or lodestone~~)~~. • Magnets have important applications and uses in everyday life.	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify the north and south magnetic poles of magnets. • use magnetic compasses to determine the directions of north and south poles. • predict which materials will be attracted to magnets, test the predictions, and create a chart that shows the results, classifying materials as to whether they are attracted to magnets or not. • conduct an investigation to determine how the different poles of magnets react to the poles of other magnets. • identify important applications of magnets in everyday life: - refrigerator magnets and chalkboard letters - toys - door latches - paper clip holders - computers - motors - credit card magnetic strips. • compare natural magnets (lodestone or magnetite) and artificial magnets. • create a new application for using a magnet.

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, ~~states~~ phases of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure of classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

2.3	The student will investigate and understand basic properties of solids, liquids, and gases. Key concepts include a) identification of distinguishing characteristics of solids, liquids, and gases; b) measurement of the mass and volume of solids and liquids; and c) changes in phases of matter with the addition or removal of energy.

~~Understanding the Standard~~ Overview

This standard continues to focus on matter. In 2.3 students build upon the knowledge introduced in K.4 and 1.3. In K.4 physical properties of matter are investigated and the properties of water are observed and tested. In 1.3 students investigate how common materials interact with water. In 2.3 students investigate, by conducting simple experiments, the properties of solids, liquids, and gases. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

2.3 The student will investigate and understand basic properties of solids, liquids, and gases. Key concepts include
a) identification of distinguishing characteristics of solids, liquids, and gases;
b) measurement of the mass and volume of solids and liquids; and
c) changes in phases of matter with the addition or removal of energy.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • All ~~common~~ substances are made of matter. • Matter is anything that has mass and takes up space. • Solids have a defined shape and volume. • Liquids have a definite volume and take the shape of the container. • Gases will completely fill any closed container (take the shape of its container) and assume the volume of its container. (e.g., Helium gas put into a balloon takes the shape of the balloon because the balloon defines its shape.) • Mass is a measure of the amount of matter. • Weight is the measure of the gravitational pull on an object. • Volume is the measure of the amount of space occupied by matter. • Matter most commonly occurs in three ~~states~~ phases: solids, liquids, and gases. • Matter can change from one ~~state~~ phase to another. • When matter changes from one ~~state~~ phase to another, these changes are referred to as physical changes. • Changes from solid to liquid to gas require ~~heat~~ the addition of energy.	In order to meet this standard, it is expected that students ~~should be able to~~ will • classify materials as to whether they are liquids, solids, or gases. • describe and identify examples of condensation, evaporation, melting, and freezing of water. • measure the mass of solids and the volume of liquids in metric and standard English units. • examine and describe the transformation of matter from one ~~state~~ phase to another, i.e., solid water (ice) to liquid (water) to gas (steam). • conduct an investigation to observe the condensation of water. • design and conduct an investigation to determine basic factors that affect the evaporation of water. • identify the phases of water and the uses of water in its various phases in the home and at school.

Life Processes

This strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards K.6, K.7, 1.4, 1.5, 2.4, 3.4, and 4.4.

2.4	The student will investigate and understand that plants and animals undergo a series of orderly changes as they mature and grow. Key concepts include a) animal life cycles; and b) plant life cycles.

~~Understanding the Standard~~ Overview

In 2.4 students investigate and understand that plants and animals undergo change throughout their lives. This concept builds upon K.6 in which students learn about classifying things as living and nonliving. In K.7 ~~in~~ ~~which~~ students learn about the basic needs and life processes of animals~~;~~. ~~And~~ In 1.4, ~~in which~~ they learn that plants have life needs, ~~and~~ functional parts, and can be classified according to certain characteristics. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

2.4	The student will investigate and understand that plants and animals undergo a series of orderly changes as they mature and grow. Key concepts include a) animal life cycles; and b) plant life cycles.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Throughout their lives, plants and animals undergo a series of orderly and identifiable changes. • Changes in ~~living things~~ organisms over time occur in cycles and differ among the various plants and animals. • Some animals, such as mealworms, pill bugs, frogs, and butterflies~~,~~ go through distinct stages as they mature to adults. Other animals, such as crickets, praying mantis, gray squirrels, and white-tailed deer, resemble their parents from birth to maturity and do not have distinct stages. • White-tailed deer are the largest herbivores in Virginia. They are found in all areas of Virginia including forests, open fields, mountain tops, coastal islands, and in cities and towns. Their diet consists of grasses, leaves, nuts, fruits, and fungi. Virginia's white-tailed deer have few predators. Predation in Virginia is mainly in the form of harassment by dogs. Fawns may be taken by bobcat. Mortality factors include hunting, motor vehicles, poaching, depredation, dogs, fences, cripples, and trains respectively. • Newborn white-tailed deer are called fawns. They become yearlings at 14 to 18 months of age. As adults, males are called bucks and females are called does. White-tailed deer are tan or reddish brown in the summer and grayish brown in the winter. The underside and throat are white, and the tail is brown above and white below. • A white-tailed deer's lifespan averages eight years. • Of the more than 200,000 kinds of vascular plants in the world today over 95 percent flower at some time in their lives. The best-known flowers are bright and colorful but others, like those of grasses, are small	In order to meet this standard, it is expected that students ~~should be able to~~ will • describe changes in the life cycle of ~~a frog and~~ a butterfly and a white-tailed deer. • ~~identify and describe changes in a plant from flower (blossom) to fruit.~~ • compare and contrast life cycles of ~~a frog and~~ a butterfly and a white-tailed deer. • identify the stages in the life cycle of a flowering plant. • construct and interpret models/diagrams of animal and plant life cycles.

2.4 The student will investigate and understand that plants and animals undergo a series of orderly changes as they mature and grow. Key concepts include a) animal life cycles; and b) plant life cycles.	
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
and inconspicuous. • The basic stages in the life cycle of flowering plants include: seeds, germination of the seed, growth of the stem and roots, growth of leaves, growth of flowers, fertilization (pollination) of the flowers, production of fruit/new seeds, and death. • ~~An important part of the life cycle of a flowering plant is the formation of the flower to the development of the fruit.~~	

Grade Two
Science Strand

Living Systems

This strand begins in second grade and builds from basic to more complex understandings of a system, both at the ecosystem level and at the level of the cell. The concept of kingdoms of living ~~things~~ organisms and a general classifying of organisms are also presented. The other major topics developed in the strand include the types of relationships among organisms in a food chain, different types of environments and the organisms they support, and the relationship between organisms and their nonliving environment. This strand includes science standards 2.5, 3.5, 3.6, 4.5, 5.5, and 6.7.

2.5	The student will investigate and understand that living things are part of a system. Key concepts include a) living organisms are interdependent with their living and nonliving surroundings; b) an animal's habitat includes adequate food, water, shelter or cover, and space; c) habitats change over time due to many influences; and d) fossils provide information about living systems that were on Earth years ago.

~~Understanding the Standard~~ Overview

In K.6 students are introduced to the concept of living and nonliving. Students are introduced to living systems in 2.5 and investigate and understand that living ~~things~~ organisms interact with other living ~~things~~ organisms and their surroundings. The formal word system is introduced in this standard. The expectation is that students understand the concept in terms of the interactions between living and nonliving things. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

2.5 The student will investigate and understand that living things are part of a system. Key concepts include
a) living organisms are interdependent with their living and nonliving surroundings;
b) an animal's habitat includes adequate food, water, shelter or cover, and space;
c) habitats change over time due to many influences; and
d) fossils provide information about living systems that were on Earth years ago.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Living ~~things~~ organisms are dependent on other living ~~things~~ organisms and their nonliving surroundings for survival. • All of the interactions between and among living ~~things~~ organisms and their nonliving surroundings are referred to as a system. • Shelter may be living (coral, tree) or nonliving (caves, houses). • The habitat of an animal includes adequate food, water, shelter or cover, and space. If any of the basic elements of an animal's habitat are absent, the animal's survival is threatened. The animal may adapt or leave the area. • The habitats of living ~~things~~ organisms, such as forests, grasslands, rivers, and streams, change due to many human or natural influences (e.g., forest fires, hurricanes, and droughts). Habitats change from season to season. • Fossils found provide scientists with information about plants and animals that lived on Earth many years ago. (e.g., The rise and fall of sea level is recorded in the richly fossiliferous rocks of Virginia's coastal plain. An abundance of marine fossils – fossil clams, snails, sand dollars, shark's teeth, and whalebones – can be found in Virginia's coastal plains.) • Virginia's state fossil, Chesapecten jeffersonius, is a large extinct species of scallop that dates to approximately 4.5 million years ago. It was the first fossil ever described in North America and is named after Thomas Jefferson, one of our founding fathers, and an amateur paleontologist.	In order to meet this standard, it is expected that students ~~should be able to~~ will • classify objects as to whether they are living or nonliving. • describe the basic components of an animal habitat (food, water, shelter or cover, and space). • classify the parts of an animal's habitat as living or nonliving. • ~~describe the nonliving components of an organism's surroundings, including water, space, and shelter. (Shelter may be living or nonliving.)~~ • construct and interpret simple models of different kinds of habitats, including a forest and a stream. • predict and describe seasonal changes in habitat and their effects on plants and animals, for example, how trees change through the seasons and how animals respond to changes in the seasons. • describe how animals are dependent on their surroundings, for example, how squirrels and other animals are affected by the loss of forest habitat. • describe how scientists use the study of fossils to show past weather/climate conditions~~-~~and environmental characteristics.

Grade Two
Science Strand

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of how Earth systems are connected and how the Earth interacts with other members of the solar system. The topics developed include shadows; relationships between the sun and the Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards ~~K.7~~ K.8, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

2.6	The student will investigate and understand basic types, changes, and patterns of weather. Key concepts include a) identification of common storms and other weather phenomena; b) the uses and importance of measuring, recording, and interpreting weather data; and c) the uses and importance of tracking weather data over time.

~~Understanding the Standard~~ Overview

In ~~K.8~~ K.9 students conduct weather observations~~, and~~. ~~i~~In 1.6 and 1.7 students are introduced to the concept that the sun is the source of ~~heat energy and light~~ energy for the Earth, and ~~to the ways~~ that ~~heat energy, light~~ the sun's energy~~,~~ and precipitation affect people and other living things. In 2.6 students investigate and understand types of weather and weather patterns and measure and record current weather data. Students also explore the uses of tracking weather data over time. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

2.6 The student will investigate and understand basic types, changes, and patterns of weather. Key concepts include
a) identification of common storms and other weather phenomena;
b) the uses and importance of measuring, recording, and interpreting weather data; and
c) the uses and importance of tracking weather data over time.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • The Earth's weather changes continuously from day to day. • Changes in the weather are characterized by daily differences in wind, temperature, and precipitation. • Precipitation occurs when water, previously evaporated, condenses out of the air and changes ~~state~~ its phase from a gas to a liquid (rain) or to a solid (snow or sleet). • Extremes in the weather, such as too little or too much precipitation, can result in droughts or floods. • Storms have powerful winds, which may be accompanied by rain, snow, or other kinds of precipitation. • Weather data ~~is~~ are collected and recorded using instruments. This information is very useful for predicting weather and determining weather patterns. • Weather influences human activity. • Scientists collect weather data over time to study trends and patterns. These trends and patterns help them to make future weather predictions.	In order to meet this standard, it is expected that students ~~should be able to~~ will • observe and describe seasonal weather patterns and local variations. • observe and record daily weather conditions, such as sunny, cloudy, windy, rainy, or snowy. • record and interpret daily temperature, using a graph with numbered axes. • measure and record weather data, using weather instruments, including a thermometer, rain gauge, and weather vane (standard English and metric measures). • describe weather in terms of temperature, wind, and precipitation. • observe and describe precipitation in terms of evaporation and condensation of water. • observe and describe types of precipitation, including rain, snow, and ice (sleet and hail). • describe how tracking weather data over time helps scientists make future weather predictions. • evaluate the influence of daily weather conditions on personal activities and dress. • identify common types of storms. Examples include hurricanes, tornadoes, blizzards, and thunderstorms. • compare and contrast droughts and floods.

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living things. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, our solar system, and change in the Earth's surface over time. This strand includes science standards ~~K.8,~~ K.9, K.10, 1.7, 2.7, 3.8, 3.9, 4.7, 4.8, and 5.7.

2.7	The student will investigate and understand that weather and seasonal changes affect plants, animals, and their surroundings. Key concepts include a) effects of weather and seasonal changes on the growth and behavior of living things; and b) weathering and erosion of land surfaces.

~~Understanding the Standard~~ Overview

Students are introduced to the concepts of patterns, cycles, and change in standards ~~K.8~~ K.9 and ~~K.9~~ K.10. These concepts include, in ~~K.8~~ K.9, weather observations, shapes and forms of common natural objects (seeds, cones, and leaves), and animal and plant growth~~, and home and school routine~~. ~~K.9~~ K.10 introduces concepts that include natural and human-made ~~things~~ objects that change over time, either fast or slow, and that change can be measured. In 1.7 students investigate and understand the relationship between seasonal change and weather. Important concepts include how plants, animals, and people respond to changes in light, temperature, and precipitation. In 2.7 the students investigate and understand that weather and seasons affect plants, animals, and their surroundings. The effects of weather and seasonal changes on weathering and erosion of the land surface are included in 2.7. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

2.7 The student will investigate and understand that weather and seasonal changes affect plants, animals, and their surroundings. Key concepts include

a) effects of weather and seasonal changes on the growth and behavior of living things; and
b) weathering and erosion of land surfaces.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Living ~~things~~ organisms respond to weather and seasonal changes. This can be reflected in changes in growth and behavior. • ~~Adverse~~ Conditions of weather may slow the growth and development of plants and animals ~~*(dormancy)*~~, whereas optimal weather conditions may accelerate the growth and development of plants and animals. • Dormancy is a state of reduced metabolic activity adopted by many organisms (both plants and animals) under conditions of environmental stress or when such stressful conditions are likely to appear, such as in winter. • Many trees produce new leaves in the spring and lose them in the fall due to seasonal changes in temperature and light. • The outward coloration and coloration patterns of many animals are similar in appearance to the plants in the places in which they live. This similarity to background is referred to as camouflage, and it enables animals to hide and avoid those that may eat or harm them. • Some animals (e.g., geese, monarch butterflies, tundra swans) ~~migrate~~ travel from one place to another and back again (migration) in search of a new temporary habitat because of climate, availability of food, season of the year, or reproduction. • Some animals (e.g., groundhogs, black bears) ~~or~~ go into a deep sleep (hibernation) due to seasonal changes. Hibernation is a condition of biological rest or inactivity where growth, development, and metabolic processes slow down. • ~~Some animals (geese, monarch butterflies) Some animals (bears,~~	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify growth and behavioral responses of plants and animals to weather and seasonal changes. Examples of responses that are adaptive include migration, hibernation, camouflage, and dormancy. • identify animals that migrate, hibernate, or show other changes throughout the seasons or in the presence of adverse environmental conditions. • evaluate the usefulness of camouflage in an animal's habitat (for example, coloration patterns ~~in~~ of frogs). • compare and contrast the responses of plants and animals to weather and seasonal changes. • model the effects of weathering and erosion on the land surface.

2.7	The student will investigate and understand that weather and seasonal changes affect plants, animals, and their surroundings. Key concepts include a) effects of weather and seasonal changes on the growth and behavior of living things; and b) weathering and erosion of land surfaces.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~groundhogs) hibernate.~~ • Some animals undergo physical changes (e.g., thickening of dog fur in the winter and shedding in the summer) from season to season. • Land surfaces are subject to the agents of weathering and erosion. Land surfaces that are not covered with or protected by plants are more likely to be subject to the loss of soil by wind and water. • Weathering is the breaking down of rocks, which usually happens over long periods of time. • Erosion is the process by which the products of weathering are moved from one place to another. Erosion may happen quickly (e.g., during a flood or a hurricane) or over a long period of time.	

Earth Resources

This strand focuses on student understanding of the role of resources in the natural world and how people can utilize those resources in a sustainable way. An important idea represented in this strand is the concept of management of resource use. This begins with basic ideas of conservation and proceeds to more abstract consideration of costs and benefits. The topics developed include conservation of materials, soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards ~~K.10~~ K.11, 1.8, 2.8, 3.10, 3.11, ~~4.8~~ 4.9, and 6.9.

2.8	The student will investigate and understand that plants produce oxygen and food, are a source of useful products, and provide benefits in nature. Key concepts include a) important plant products are identified and classified; b) the availability of plant products affects the development of a geographic area; c) plants provide oxygen, homes, and food for many animals; and d) plants can help reduce erosion.

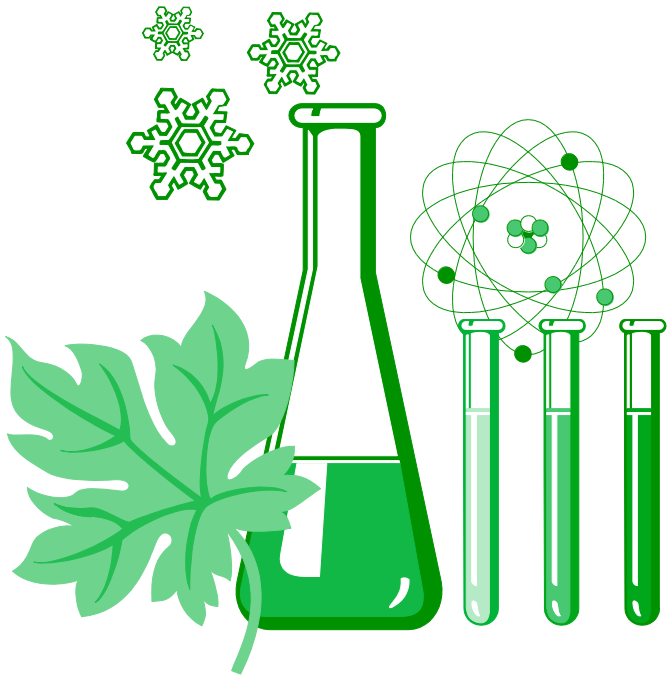
~~Understanding the Standard~~ Overview

In ~~K.10~~ K.11 students investigate and understand that materials can be used, recycled, and conserved, while in 1.8 students investigate and understand that natural resources, which are identified as plants, animals, water, air, land, minerals, forests, and soil, are limited. In 2.8 students investigate and understand that plants produce oxygen and food, are a source of useful products, and provide benefits in nature. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

2.8 The student will investigate and understand that plants produce oxygen and food, are a source of useful products, and provide benefits in nature. Key concepts include

a) important plant products are identified and classified;
b) the availability of plant products affects the development of a geographic area;
c) plants provide oxygen, homes, and food for many animals; and
d) plants can help reduce erosion.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Plants provide many useful products and materials, which benefit human beings as well as other living ~~things~~ organisms. • Plant products include such essentials as oxygen and food, as well as materials useful for clothing and shelter. • Plants may grow well ~~only~~ in certain geographic areas, thus enabling the production of plant products that allow humans to live in ~~as well as to~~ and ~~develop~~ thrive in those areas. • Some examples of plants that grow in Virginia's geographic regions include: - Coastal Plains (Tidewater): peanuts, cotton, soybeans; - Piedmont: apples, tobacco, cabbage; - Blue Ridge Mountains: evergreens, apples, corn; - Valleys and Ridges: evergreens, apples, corn; and - Appalachian Plateau: tobacco. • Plants provide homes and food sources for many animals. • Plants ~~are also~~ are important ~~agents~~ in the prevention of soil erosion. • Products from plants include, but are not limited to, cinnamon from the bark of trees; fiber from reeds, grasses and trees; ~~and~~ cotton from a cotton plant~~.~~; ~~S~~spices ~~come~~ from various plant parts~~,~~; lumber ~~comes~~ from wood~~,~~; rubber ~~comes~~ from rubber trees~~,~~; and medicines (e.g., aloe vera from the aloe plant, quinine from the bark of Cinchona trees found in South America to treat malaria).	In order to meet this standard, it is expected that students ~~should be able to~~ will • ~~comprehend~~ understand that plants produce oxygen and food. • classify and identify the sources and uses of plant products, such as fiber, cotton, oil, spices, lumber, rubber, medicines, and paper. • describe how the availability of certain plant products in a geographic area would affect the development of that area. • describe plant products grown in Virginia that are useful to people, including wood, fruits, and vegetables. List and classify plant products (e.g., peanuts, cotton, soybeans, apples, evergreens). • compare and contrast different ways animals use plants as homes and shelters. • construct and interpret a chart illustrating the plant foods consumed by different animals. • construct and interpret a model that demonstrates how plants ~~prevent~~ reduce soil erosion.



Science Standards of Learning Curriculum Framework

Grade Three

Final Review
November 18, 2010

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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Grade Three
Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student ~~should~~ will be able to do when conducting activities and investigations, and represents the student understanding of the nature of science. The various skill categories are described in the "Investigate and Understand" section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 3.1 represent more specifically what a student should be able to do as a result of science experiences in third grade. Across the grade levels, the skills in the "Scientific Investigation, Reasoning, and Logic" strand form a nearly continuous sequence of investigative skills and an understanding of the nature of science. ~~(Please note Appendix, "Science Skills, Scope, & Sequence.")~~ It is important that the classroom teacher understand~~s~~ how the skills in standard 3.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). The third-grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed. ~~It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in the "Scientific Investigation, Reasoning, and Logic" strand.~~

3.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) observations are made and are repeated to ensure accuracy;
b) predictions are formulated using a variety of sources of information;
c) objects with similar characteristics or properties are classified into at least two sets and two subsets;
d) natural events are sequenced chronologically;
e) length, volume, mass, and temperature are estimated and measured in metric and standard English units using proper tools and techniques;
f) time is measured to the nearest minute using proper tools and techniques;
g) questions are developed to formulate hypotheses;
h) data are gathered, charted, graphed, and analyzed;
i) unexpected or unusual quantitative data are recognized;
j) inferences are made and conclusions are drawn;
k) data are communicated;
l) models are designed and built; and
m) current applications are used to reinforce science concepts.

~~Understanding the Standard~~ Overview

The skills defined in standard 3.1 are intended to define the "investigate" component and the understanding of the nature of science ~~of~~ for all of the other third-grade standards (3.2–3.11). The intent of standard 3.1 is that students will continue to develop a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed at the third grade, and continue to strengthen their understanding of the components of the nature of science. **Standard 3.1 does not require a discrete unit be taught on scientific investigation and the nature of science because the ~~inquiry~~ skills that make up the standard should be incorporated in all the other third-grade standards.** For example, it is not expected that teachers should develop a separate unit on the metric system, but that they should integrate metric measurement into the teaching of the rest of the third-grade standards. It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science as well as more fully grasp the content-related concepts.

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~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts: a) the natural world is understandable; b) science is based on evidence, both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. In grade three, an emphasis should be placed on concepts a, b, c, and e. • Science assumes that the natural world is understandable. Scientific inquiry can provide explanations about nature. This expands students' ~~knowledge~~ thinking from just a knowledge of facts to understanding ~~why~~ how ~~the~~ facts are relevant to everyday life.	In order to meet this standard, it is expected that students ~~should be able to~~ will • make and communicate careful observations. • demonstrate that observations should be repeated to ensure accuracy. • classify objects into at least two major sets and subsets based on similar characteristics, such as predator/prey and herbivore, carnivore, and omnivore. • sequence natural events chronologically~~.~~ (Example: ~~3.9~~ 3.8 — plant and animal life cycles, phases of the moon, the water cycle, and tidal change). • measure length to the nearest centimeter, mass to the nearest gram, volume to the nearest milliliter, temperature to the nearest degree Celsius, and time to the nearest minute, using the appropriate instrument. • develop hypotheses from simple questions. These questions should be related to the concepts in the third-grade standards. Hypotheses should

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~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• Science demands evidence. Scientists develop their ideas based on evidence and they change their ideas when new evidence becomes available or the old evidence is viewed in a different way. • Science uses both logic and innovation. Innovation has always been an important part of science. Scientists draw upon their creativity to visualize how nature works, using analogies, metaphors, and mathematics. • Science is a complex social activity. It is a complex social process for producing knowledge about the natural world. Scientific knowledge represents the current consensus as to what is the best explanation for phenomena in the natural world. This consensus does not arise automatically, since scientists with different backgrounds from all over the world may interpret the same data differently. To build a consensus, scientists communicate their findings to other scientists and attempt to replicate one another's findings. In order to model the work of professional scientists, it is essential for third-grade students to engage in frequent discussions with peers about their understanding of their investigations.	be stated in terms such as: "If an object is cut into smaller pieces, then the physical properties of the object and its smaller pieces will remain the same." • analyze data that have been gathered and organized. • communicate results of investigations by displaying data in the form of tables, charts, and graphs. Students will construct bar and picture graphs and line plots to display data~~.~~ (Example: 3.7 — comparison of types of soil and their effect on plant growth). • communicate any unexpected or unusual quantitative data that are noted. • make and communicate predictions about the outcomes of investigations. • design and build a model to show experimental results.

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~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• Questions frequently arise from observations. Hypotheses can be developed from those questions. Data gathered from an investigation may support a hypothesis. A hypothesis is a statement written in a manner that describes the cause and effect relationship between the independent and dependent variables in an experiment. At the third-grade level, a method for helping students understand how to develop a hypothesis is to have them build "if/then" statements (e.g., If heat is added to ice, then the ice will melt.). • Complete observations are made using all of the senses. Simple instruments can help extend the senses (e.g., magnifying glass enhances the vision of an item). • Predictions are statements of what is expected to happen in the future based on past experiences and observations. • In order for data from an investigation to be most useful, it must be organized so that it can be examined more easily. • Charts and graphs are powerful tools for reporting and organizing data. • It is sometimes useful to organize objects according to similarities and	

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~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
differences. By organizing objects in sets and subsets, it may be easier to determine a specific type of characteristic. • An inference is a ~~conclusion~~ tentative explanation based on ~~evidence~~ background knowledge and available data. • A conclusion is a summary statement based on the results of an investigation. • Putting natural events in a sequence allows us to notice change over time. • Metric measures, including centimeters, grams, milliliters, and degrees Celsius, are a standard way to record measurements. The metric system is recognized everywhere around the world. • When using any standard measurement scale, measure to the marked increment and estimate one more decimal place. Scientists do not round their measurements as this would be inaccurate. • A bar graph can be horizontal or vertical, and it compares amounts. Both the X- and Y-axis need to be identified. ~~Discrete data are found on a bar graph.~~	

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~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• A line plot shows the spread of data. *(See Grade 3 Mathematics Curriculum Framework, Standard ~~3.21~~ 3.17, page ~~32~~ 31.)* • A picture graph is similar to a bar graph except that it uses symbols to represent quantities. • Scientists use a variety of modes to communicate about their work. Examples of ways they communicate include oral presentations; graphs and charts created to visualize, analyze and present information about their data; and written reports. • In science, it is important that experiments and the observations recorded are replicable. There are two different types of data – qualitative and quantitative. Qualitative data deal with descriptions and data that can be observed, but not measured precisely. Quantitative data are data that can be counted or measured and the results can be recorded using numbers. Quantitative data can be represented visually in graphs and charts. Quantitative data define, whereas qualitative data describe. Quantitative data are more valuable in science because they allow direct comparisons between observations made by different people or at different times.	

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~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes

Example of Qualitative Data vs. Quantitative Data

Third-Grade Class

Qualitative Data	Quantitative Data
• Friendly • Like science • Positive about schoolwork	• 25 students • 10 girls, 15 boys • 68 percent have perfect attendance

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

3.2	The student will investigate and understand simple machines and their uses. Key concepts include a) purpose and function of simple machines; b) types of simple machines; c) compound machines; and d) examples of simple and compound machines found in the school, home, and work environments.

~~Understanding the Standard~~ Overview

This standard introduces students to six types of simple machines, their uses, and examples of these six machines found in everyday environments. These simple machines function to make doing work easier. Activities should focus on identifying the six simple machines, explaining how they operate, and locating examples in everyday life that make a task easier at home, in school, and in the workplace. The students should have experiences using the simple and compound machines to determine how each makes a task easier. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

3.2 The student will investigate and understand simple machines and their uses. Key concepts include
a) purpose and function of simple machines;
b) types of simple machines;
c) compound machines; and
d) examples of simple and compound machines found in the school, home, and work environments.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Simple machines are tools that make work easier. Examples of tasks made easier include lifting a heavy weight, moving a heavy object over a distance, pushing things apart, changing the direction of a force, or holding an object together. • The six simple machines are the lever, inclined plane, wedge, wheel and axle, screw, and pulley. • The lever is a stiff bar that moves about a fixed point (fulcrum). It is a simple machine that is used to push, pull, or lift things. Examples include a seesaw, crowbar, and shovel. • The inclined plane is a flat surface that is raised so one end is higher than the other. The inclined plane helps move heavy objects up or down. An example is a ramp. • The wedge is wide at one end and pointed at the other to help cut or split other objects. Examples include a knife or ax. • The wheel and axle consists of a rod attached to a wheel. A wheel and axle makes it easier to move or turn things. Examples include bicycle wheels, roller skates, and a door knob. • The screw is an inclined plane wrapped around a cylinder or cone. A common use of the screw is to hold objects together. Examples include a jar lid and wood screw. • The pulley is a wheel that has a rope wrapped around it. Pulleys can be used to lift heavy objects by changing the direction or amount of the force. Examples include a flagpole.	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify and differentiate the six types of simple machines: lever, screw, pulley, wheel and axle, inclined plane, and wedge. • differentiate and classify specific examples of simple machines found in school and household items. These include a screwdriver, nutcracker, screw, flagpole pulley, ramp, and seesaw. • analyze the application of and explain the function of each of the six types of simple machines. An example would be that an inclined plane is a ramp to make it easier for a heavy object to be moved up or down. • identify and classify the simple machines which compose a compound machine, such as scissors, wheelbarrow, and bicycle. • design and construct an apparatus that contains a simple machine.

3.2 The student will investigate and understand simple machines and their uses. Key concepts include a) purpose and function of simple machines; b) types of simple machines; c) compound machines; and d) examples of simple and compound machines found in the school, home, and work environments.	
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
• A compound machine is a combination of two or more simple machines. Examples include scissors, wheelbarrow, and bicycle.	

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, ~~states~~ phases of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure of classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

3.3	The student will investigate and understand that objects are made of materials that can be described by their physical properties. Key concepts include a) objects are made of one or more materials; b) physical properties remain the same as the material is changed in visible size; and c) visible physical changes are identified.

~~Understanding the Standard~~ Overview

Students should understand that all objects are made of materials that have observable physical properties. Every object that takes up space is made of matter. Materials can be different colors, shapes, textures, or sizes. They can be hard or soft. The properties of objects can be used to sort or classify them. If materials are broken down into smaller visible parts, each of these smaller parts still has the same physical properties as the original material. (Clear examples include plastics, metal, paper, and ice. Substances that are coarse mixtures, ~~i.e.,~~ e.g., many types of rock, are not good examples.) ~~This standard introduces the concept that materials are made up of smaller parts that are too small to be seen without magnification.~~ It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

3.3 The student will investigate and understand that objects are made of materials that can be described by their physical properties. Key concepts include

a) objects are made of one or more materials;
b) physical properties remain the same as the material is changed in visible size; and
c) visible physical changes are identified.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Objects are made of one or more materials (e.g., toys, shoes, and furniture). • ~~All materials are composed of parts too small to be seen without magnification.~~ • Physical properties (e.g., color, texture, phase, temperature, ability to dissolve in water) remain the same even if the visible material (e.g., plastic, paper, metal, ice) is reduced in size. • Nanotechnology is the study of materials at the molecular (atomic) scale. Items at this scale are so small they are no longer visible with the naked eye. Nanotechnology has shown that the behavior and properties of some substances at the nanoscale (a nanometer is one-billionth of a meter) contradict how they behave and what their properties are at the visible scale.	In order to meet this standard, it is expected that students ~~should be able to~~ will • explain that physical properties are observable characteristics that enable one to differentiate objects. • infer that objects are made of one or more materials based on observations of the physical properties that are common to each individual object. • compare the physical properties of smaller, visible pieces of a material to those physical properties of the entire material. • conclude that materials have their own set of physical properties that are observable. • design an investigation to determine if the physical properties of a material will remain the same if the material is reduced in size.

Life Processes

This strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards K.6, K.7, 1.4, 1.5, 2.4, 3.4, and 4.4.

3.4	The student will investigate and understand that adaptations allow animals to satisfy life needs and respond to the environment. Key concepts include a) behavioral adaptations; and b) physical adaptations.

~~Understanding the Standard~~ Overview

Students will compare and contrast the physical and behavioral characteristics of different animals that allow the animals to adapt and respond to life needs. The students will need to describe specific examples of how animals gather food, find shelter, defend themselves, and rear young. The concepts of hibernation, migration, camouflage, mimicry, instinct, and learned behavior are specific ways in which animals respond to their environment. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

3.4 The student will investigate and understand that adaptations allow animals to satisfy life needs and respond to the environment. Key concepts include
a) behavioral adaptations; and
b) physical adaptations.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • In order to survive, animals act in different ways to gather and store food, find shelter, defend themselves, and rear their young. • Physical adaptations help animals survive in their environment (~~Examples include~~ e.g., camouflage, ~~and~~ mimicry). • Various animals possess adaptations which help them blend into their environments to protect themselves from enemies (camouflage). Camouflage is the means by which animals escape the notice of predators, usually because of a resemblance to their surroundings using coloration or outer coverage patterns. • Mimicry occurs when a species has features similar to another species. Either one or both are protected when a third species cannot tell them apart. (Mimicry happens in both animal and plant species.) Some animals look like other animals to avoid being eaten (mimicry). This adaptation helps protect them from their predators. (For example, the viceroy butterfly tastes good to birds, but the monarch butterfly tastes bad. Because the viceroy looks like the monarch butterfly, it is safer from predators.) Mimicry can also occur as mimicked behaviors, mimicked sounds, or mimicked scents~~, or mimicked locations~~. • Behavioral adaptations allow animals to respond to life needs. Examples include hibernation, migration, dormancy, instinct, and learned behavior. • Some animals (e.g., groundhogs, black bears) go into a deep ~~winter~~ sleep in which their body activities slow down due to seasonal changes and they can live off stored food (hibernation). Hibernation is a condition of biological rest or inactivity where growth, development, and metabolic processes slow down.	In order to meet this standard, it is expected that students ~~should be able to~~ will • give examples of methods that animals use to gather and store food, find shelter, defend themselves, and rear young. • describe and explain the terms ~~hibernation, migration,~~ camouflage, mimicry, hibernation, migration, dormancy, instinct, and learned behavior. • explain how an animal's behavioral adaptations help it live in its specific habitat. • distinguish between physical and behavioral adaptations of animals. • compare the physical characteristics of animals, and explain how the animals are adapted to a certain environment. • compare and contrast instinct and learned behavior. • create (model) a camouflage pattern for an animal living in a specific dry-land or water-related environment. (Relates to 3.6.) • design and construct a model of a habitat for an animal with a specific adaptation.

3.4	The student will investigate and understand that adaptations allow animals to satisfy life needs and respond to the environment. Key concepts include a) behavioral adaptations; and b) physical adaptations.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• Some animals (e.g., geese, monarch butterflies, tundra swans) go on a long-distance journey from one place to another ~~as seasons change~~ (migration) in search of a new temporary habitat because of climate, availability of food, season of the year, or reproduction. • Dormancy is a state of reduced metabolic activity adopted by many organisms (both plants and animals) under conditions of environmental stress or, when such stressful conditions are likely to appear, as in winter. • Some animals are born with natural behaviors that they need in order to survive in their environments (instincts). These behaviors are not learned but are instinctive, such as a beaver building a dam or a spider spinning a web. • Some behaviors need to be taught in order for the animal to survive, such as a bear cub learning to hunt (learned behavior).	

Grade Three
Science Strand

Living Systems

This strand begins in second grade and builds from basic to more complex understandings of a system, both at the ecosystem level and at the level of the cell. The concept of kingdoms of living ~~things~~ organisms and a general classifying of ~~organisms~~ them are also presented. The other major topics developed in the strand include the types of relationships among organisms in a food chain, different types of environments and the organisms they support, and the relationship between organisms and their nonliving environment. This strand includes science standards 2.5, 3.5, 3.6, 4.5, 5.5, and 6.7.

3.5	The student will investigate and understand relationships among organisms in aquatic and terrestrial food chains. Key concepts include a) producer, consumer, decomposer; b) herbivore, carnivore, omnivore; and c) predator and prey.

~~Understanding the Standard~~ Overview

This standard focuses on student understanding of the food chain in water and land environments. It focuses on the types of relationships among living ~~things~~ organisms and their dependence on each other for survival. The strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include the basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards ~~K.6~~ K.7, 1.4, 1.5, 2.4, 3.4, 4.4, and 6.7. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

3.5 The student will investigate and understand relationships among organisms in aquatic and terrestrial food chains. Key concepts include
a) producer, consumer, decomposer;
b) herbivore, carnivore, omnivore; and
c) predator and prey.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • A food chain shows a food relationship among plants and animals in a specific area or environment. • Terrestrial organisms are found on land habitats such as deserts, grasslands, and forests. Aquatic organisms are found in water habitats such as ponds, marshes, swamps, rivers, and oceans. • A green plant makes it own food ~~from~~ using sunlight, air, and water. Green plants are producers. • A consumer is an animal that eats living organisms (plant or animal). • Certain organisms break down decayed plants and animals into smaller pieces that can be used again by other living ~~things~~ organisms. These organisms are decomposers. • A food chain, which shows part of a food web, can have an animal that eats only plants (herbivore). It can have an animal that eats only other animals (carnivore). It can also have an animal that eats both plants and animals (omnivore). • An animal can hunt other animals to get its food (predator). • An animal can be hunted by another animal for food (prey).	In order to meet this standard, it is expected that students ~~should be able to~~ will • differentiate between predators and prey. • distinguish among producers, consumers, herbivores, omnivores, carnivores, and decomposers. • infer that most food chains begin with a green plant. • identify sequences of feeding relationships in a food chain. • explain how a change in one part of a food chain might affect the rest of the food chain. • create and interpret a model of a food chain showing producers and consumers.

3.6	The student will investigate and understand that ecosystems support a diversity of plants and animals that share limited resources. Key concepts include a) aquatic ecosystems; b) terrestrial ecosystems; c) populations and communities; and d) the human role in conserving limited resources.

~~Understanding the Standard~~ Overview

Students should become familiar with several specific examples of aquatic and terrestrial ~~environments~~ ecosystems and the plants and animals unique to them. The water-related ~~environments~~ ecosystems to be discussed are the pond, marshland, swamp, stream, river, and ocean, and the dry-land ~~environments~~ ecosystems to be discussed are the desert, grassland, rain forest, and forest. Water-related and dry-land ~~environments~~ ecosystems contain many types of plants and animals that often compete for the same natural resources. These resources are often shared. Students will also explore the human role in protecting and conserving limited resources in the various ecosystems. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

3.6 The student will investigate and understand that ecosystems support a diversity of plants and animals that share limited resources. Key concepts include

a) aquatic ecosystems;
b) terrestrial ecosystems;
c) populations and communities; and
d) the human role in conserving limited resources.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Water-related ~~environments~~ ecosystems include those with fresh water or salt water. Examples include ponds, marshes, swamps, streams, rivers, and oceans. • Dry-land ~~environments~~ ecosystems include deserts, grasslands, rain forests, and forests. • There are distinct differences among pond, marshland, swamp, stream, river, ocean, desert, grassland, rainforest, and forest ~~environments~~ ecosystems. • A population is a group of organisms of the same kind that lives in the same place. Examples of a population are a ~~group~~ flock of swans in a pond, a school of fish in a river, and a herd of cattle in the grassland. • A community is all of the populations that live together in the same place. An example of a dry-land community would be a forest made up of trees, squirrels, worms, rabbits, and hawks. An example of a water-related community would be an ocean made up of fish, crabs, and seaweed. • Organisms compete for the limited resources in their specific ~~environment~~ ecosystem. • Humans need to help conserve limited resources.	In order to meet this standard, it is expected that students ~~should be able to~~ will • describe major water-related ~~environments~~ ecosystems and examples of animals and plants that live in each. • describe major dry-land ~~environments~~ ecosystems and examples of animals and plants that live in each. • compare and contrast water-related and dry-land ~~environments~~ ecosystems. • explain how animals and plants use resources in their ~~environment~~ ecosystem. • distinguish between a population and a community. • predict what would occur if a population in a specific ~~environment~~ ecosystem ~~were~~ was to die. • analyze models or diagrams of different water-related ~~environments~~ ecosystems in order to describe the community of organisms each contains and interpret how the organisms use the resources in that ~~environment~~ ecosystem. • analyze models or diagrams of different dry-land ~~environments~~ ecosystems in order to describe the community of organisms each contains and interpret how the organisms use the resources in that environment. • list ways that humans can help conserve limited resources.

Grade Three
Science Strand

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of how Earth systems are connected and how the Earth interacts with other members of the solar system. The topics developed include shadows; relationships between the sun and the Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards ~~K.7,~~ K.8, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

3.7	The student will investigate and understand the major components of soil, its origin, and its importance to plants and animals including humans. Key concepts include a) soil provides the support and nutrients necessary for plant growth; b) topsoil is a natural product of subsoil and bedrock; c) rock, clay, silt, sand, and humus are components of soils; and d) soil is a natural resource and should be conserved.

~~Understanding the Standard~~ Overview

Students should know that most plants grow in soil and that people and many other animals are dependent on plants for food. The nutrients in soil are materials that plants and animals need to live and grow. Soil takes a long time to form; therefore, it should be conserved. Soil is made up of humus, silt, rock, and sand. Humus is decayed (once living) matter in soil. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

3.7 The student will investigate and understand the major components of soil, its origin, and its importance to plants and animals including humans. Key concepts include

a) soil provides the support and nutrients necessary for plant growth;
b) topsoil is a natural product of subsoil and bedrock;
c) rock, clay, silt, sand, and humus are components of soils; and
d) soil is a natural resource and should be conserved.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Soil is important because many plants grow in soil, and it provides support and nutrients for the plants. • Over many years, weather, water, and living ~~things~~ organisms help break down rocks and create soil (weathering). • Nutrients are materials that plants and animals need to live and grow. • Rock, clay, silt, sand, and humus are components of soil. • Topsoil is the upper soil surface and a natural product of subsoil and bedrock. Topsoil is best for plant growth. • Subsoil and bedrock are layers of soil under the topsoil that are formed over a long period of time by the action of water. • Subsoil and bedrock are not as good for growing plants as is topsoil. • Humus is decayed matter in soil. It adds nutrients to the soil. It is located in the topsoil. • Clay contains tiny particles of soil that hold water well and provides nutrients. • Sand is made up of small grains of worn-down rock, has few nutrients, and does not hold water well. • Silt is made up of very small broken pieces of rock. Its particles are larger than clay and smaller than sand. • Since soil takes a long time to form, it should be conserved, not wasted.	In order to meet this standard, it is expected that students ~~should be able to~~ will • observe and recognize that soil, as a natural resource, provides the support and nutrients necessary for plant growth. • ~~comprehend~~ understand the key terminology related to soil, including humus, nutrients, topsoil, and bedrock. • interpret and illustrate a basic diagram showing major soil layers, including bedrock, subsoil, and topsoil. • analyze and describe the different components of soil, including rock fragments, clay, silt, sand, and humus. • explain how soil forms over time. • design an investigation to compare how different types of soil affect plant growth. This includes organizing data in tables and constructing simple graphs. • collect, chart, and analyze data on soil conservation on the school grounds. • evaluate the importance of soil to people. • describe how soil can be conserved.

Grade Three
Science Strand

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living ~~things~~ organisms. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, and change in the Earth's surface over time. This strand includes science standards ~~K.8,~~ K.9, K.10, 1.7, 2.7, 3.8, 3.9, 4.7, 4.8, and 5.7.

3.8	The student will investigate and understand basic patterns and cycles occurring in nature. Key concepts include a) patterns of natural events such as day and night, seasonal changes, simple phases of the moon, and tides; b) animal life cycles; and c) plant life cycles.

~~Understanding the Standard~~ Overview

This standard focuses on students understanding that many events on Earth happen in cycles or patterns. Examples of these patterns are day turning into night and night into day. Seasons cycle from fall to winter to spring to summer and back to fall. Light reflecting from the sun causes the moon to appear illuminated. The phases of the moon appear in sequence as the moon makes one revolution around ~~the~~ Earth. Seasons are caused by the tilt of ~~the~~ Earth as it revolves around the sun. The main cause of the tides is the gravitational attraction between ~~the~~ Earth and the moon. Plants and animals also undergo life cycles from birth to death. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

3.8 The student will investigate and understand basic patterns and cycles occurring in nature. Key concepts include
a) patterns of natural events such as day and night, seasonal changes, simple phases of the moon, and tides;
b) animal life cycles; and
c) plant life cycles.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • A cycle is a repeated pattern. A sequence is a series of events that occur in a natural order. • The pattern of day and night is caused by the rotation of ~~the~~ Earth. One complete rotation occurs every 24 hours. The part of ~~the~~ Earth toward the sun has daylight while the part of ~~the~~ Earth away from the sun has night. • The pattern of seasonal changes takes place because ~~the~~ Earth's axis is tilted toward or away from the sun during its revolution around the sun. Because the tilt of Earth on its axis is 23.5°, the sun's energy is not equally intense at different latitudes. Rays striking Earth near the equator do so at close to a 90° angle. Rays striking Earth near the poles do so at a much smaller angle and thus the same amount of sunlight is spread over a larger area. For this reason, the same amount of energy from the sun will be less intense nearer the poles and these areas will have a colder climate. ~~The~~ Earth takes 365 ¼ days, or one year, to make one revolution. • The cycle of moon phases ~~of the moon~~ occurs as the moon makes one revolution around ~~the~~ Earth. The ~~shapes~~ visible portion of the moon that we see each night follows a pattern. • The tides follow a pattern of two high and two low tides every 24 hours. This pattern is caused for the most part by the gravitational attraction between ~~the~~ Earth and the moon. • Plants and animals undergo life cycles~~. For example,~~ (e.g., Frogs begin as eggs in water. The eggs grow into tadpoles, the tadpoles eventually become frogs, and the adult frogs lay eggs to start ~~the~~ a new life cycle over again. In the plant life cycle, a seed grows into a new plant that	In order to meet this standard, it is expected that students ~~should be able to~~ will • explain how some events in nature occur in a pattern or cycle, such as the seasons, day and night, phases of the moon (first quarter, full, last [third] quarter, new), tides, and life cycles. • recognize that the relationships that exist between and among ~~the~~ Earth, sun, and moon result in day and night, seasonal changes, phases of the moon, and the tides. • model and describe how ~~the~~ Earth's rotation causes day and night. • model and describe how the sun's rays strike the Earth to cause seasons. • observe, chart, and illustrate phases of the moon (first quarter, full, last [third] quarter, new), and describe the changing pattern of the moon as it revolves around ~~the~~ Earth. • collect and analyze data from simple tide tables to determine a pattern of high and low tides. • explain the pattern of growth and change that organisms, such as the ~~butterfly and~~ frog and butterfly undergo during their life cycle.

3.8 The student will investigate and understand basic patterns and cycles occurring in nature. Key concepts include a) patterns of natural events such as day and night, seasonal changes, simple phases of the moon, and tides; b) animal life cycles; and c) plant life cycles.	
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
forms seeds. Then the new seeds repeat the life cycle.)	

3.9	The student will investigate and understand the water cycle and its relationship to life on Earth. Key concepts include a) there are many sources of water on Earth; b) the energy from the sun drives the water cycle; c) the water cycle involves several processes; d) water is essential for living things; and e) water on Earth is limited and needs to be conserved.

~~Understanding the Standard~~ Overview

This standard introduces students to the movement of water on ~~the~~ Earth by evaporation, condensation, and precipitation, which is called the water cycle. All the water on Earth is part of the water cycle. Water is stored in ponds, lakes, streams, rivers, ground water, and oceans. Water is essential to maintain life on Earth and should be conserved as a natural resource. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

3.9 The student will investigate and understand the water cycle and its relationship to life on Earth. Key concepts include

a) there are many sources of water on Earth;
b) the energy from the sun drives the water cycle;
c) the water cycle involves several processes;
d) water is essential for living things; and
e) water on Earth is limited and needs to be conserved.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • The water cycle is the movement of water from the ground to the air and back to the ground by evaporation, condensation, and precipitation. The energy that drives this cycle comes from the sun. • During the water cycle, liquid water is heated and changed to a gas (water vapor). ~~(~~This process is called evaporation~~)~~. The gas (water vapor) is cooled and changed back to a liquid. ~~(~~This process is called condensation~~)~~. ~~A~~ Water as a liquid or a solid falls to the ground as precipitation. • Our water supply on Earth is limited. Pollution reduces the amount of usable water; therefore, the supply should be conserved carefully. • Water is a simple compound essential for life on Earth. Living cells are mostly water. In each cell, the chemicals necessary for life are dissolved in water.	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify the sun as the origin of energy that drives the water cycle. • describe the processes of evaporation, condensation, and precipitation as they relate to the water cycle. • construct and interpret a model of the water cycle. • ~~realize living things~~ identify the different ways that organisms get water from the environment ~~in different ways~~. • identify major water sources for a community, including rivers, reservoirs, and wells. Describe the major water sources for the local community. • explain methods of water conservation in the home and school. • ~~appraise~~ identify and communicate the importance of water to people and to other living ~~things~~ organisms. • analyze possible sources of water pollution in their neighborhoods, at school, and in the local community. This includes runoff from over-fertilized lawns and fields, oil from parking lots, eroding soil, and animal waste.

Earth Resources

This strand focuses on student understanding of the role of resources in the natural world and how people can utilize those resources in a sustainable way. An important idea represented in this strand is the concept of management of resource use. This begins with basic ideas of conservation and proceeds to more abstract consideration of costs and benefits. The topics developed include conservation of materials, soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards ~~K.10~~ K.11, 1.8, 2.8, 3.10, 3.11, ~~4.8~~ 4.9, and 6.9.

3.10	The student will investigate and understand that natural events and human influences can affect the survival of species. Key concepts include a) the interdependency of plants and animals; b) the effects of human activity on the quality of air, water, and habitat; c) the effects of fire, flood, disease, and erosion on organisms; and d) conservation and resource renewal.

~~Understanding the Standard~~ Overview

This standard reinforces the concept that plants and animals are dependent upon each other for survival. Living ~~things~~ organisms depend on other living ~~thing~~ organisms to survive. Human and natural events can change habitats. Natural disasters such as fire, flood, disease, and erosion can kill organisms and destroy their habitats. Methods of ensuring the survival of plant and animal species include specific conservation measures. These are resource renewal, habitat management procedures, and species monitoring practices. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

3.10 The student will investigate and understand that natural events and human influences can affect the survival of species. Key concepts include
a) the interdependency of plants and animals;
b) the effects of human activity on the quality of air, water, and habitat;
c) the effects of fire, flood, disease, and erosion on organisms; and
d) conservation and resource renewal.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Every ~~living thing~~ organism depends on ~~every~~ other ~~living things~~ organisms to survive. This is called interdependency. • Human actions, such as polluting, can affect the survival of plants and animals. • Natural events, such as fires, floods, diseases, and erosion, can also affect the survival of plant and animal species. • Conservation is the careful use and preservation of our natural resources. • Resource renewal is a conservation practice in which species are protected. An example would be protecting endangered plants by saving their seeds, growing the seeds indoors, and later putting the new plants back in their natural habitats.	In order to meet this standard, it is expected that students ~~should be able to~~ will • explain how ~~living things~~ organisms in an area are dependent on each other. • compare and contrast human influences on the quality of air, water, and habitats. • analyze the effects of fire, flood, disease, and erosion on organisms and habitats. • describe how conservation practices can affect the survival of a species. • describe a conservation practice in the local community.

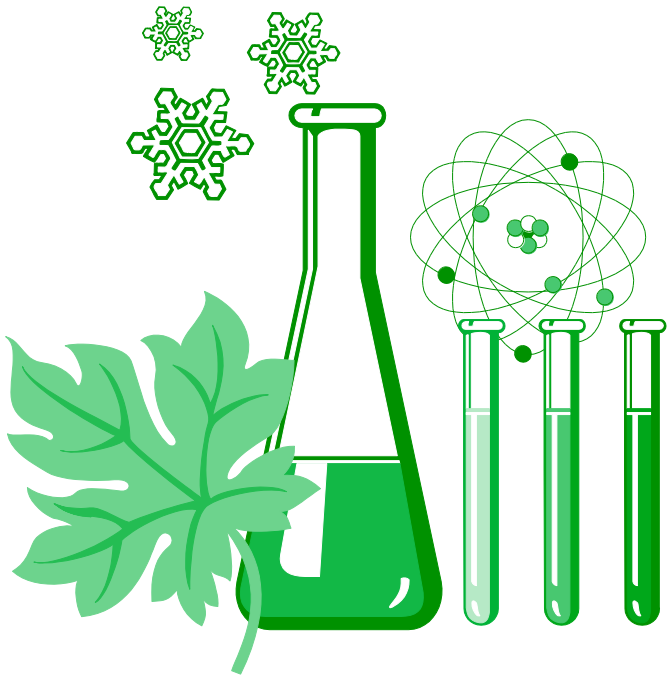
3.11	The student will investigate and understand different sources of energy. Key concepts include a) energy from the sun; b) sources of renewable energy; and c) sources of nonrenewable energy.

~~Understanding the Standard~~ Overview

This standard focuses on ~~the~~ Earth's major types of energy sources. The sun produces light and ~~heat~~ thermal energy. Natural forms of energy include sunlight, water, and wind. Important fossil fuels are coal, oil, and natural gas, which were formed over millions of years by decaying plants and animals buried in layers of rock. Sources of energy are classified either as renewable or nonrenewable. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

3.11 The student will investigate and understand different sources of energy. Key concepts include
a) energy from the sun;
b) sources of renewable energy; and
c) sources of nonrenewable energy.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • The sun is the source of almost all energy on Earth. The sun is the direct source of light and ~~heat~~ thermal energy. • Sunlight, water, and wind are sources of energy. The force of flowing water and moving air (wind) can also be used to generate electricity. • Wood comes from trees. It has many important uses, including its use as a fuel. • Some energy sources are renewable. That means that they can be replaced. Some energy sources are nonrenewable. That means that once they are used up, they are gone and cannot be replaced. Coal, oil, and natural gas are nonrenewable resources. • Fossil fuels, such as coal, oil, and natural gas, are formed from decayed plants and animals. The formation of fossil fuels takes millions of years.	In order to meet this standard, it is expected that students ~~should be able to~~ will • explain that the sun is the major source of energy for ~~the~~ Earth. • identify sources of energy and their uses. • describe how solar energy, wind, and moving water can be used to produce electricity. • describe how fossil fuels are used as an energy source. • compare and contrast renewable and nonrenewable energy sources. • analyze the advantages and disadvantages of using different naturally occurring energy sources. • design a basic investigation to determine the effects of sunlight on warming various objects and materials, including water.



Science Standards of Learning Curriculum Framework

Grade Four

Final Review
November 18, 2010

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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Grade Four
Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student ~~should~~ will be able to do when conducting activities and investigations and represents the student understanding of the nature of science. The various skill categories are described in the "Investigate and Understand" section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 4.1 represent more specifically what a student should be able to do as a result of science experiences in fourth grade. Across the grade levels, the skills in the "Scientific Investigation, Reasoning, and Logic" strand form a nearly continuous sequence of investigative skills and an understanding of the nature of science. ~~(Please note Appendix, "Science Skills, Scope, & Sequence.")~~ It is important that the classroom teacher understand~~s~~ how the skills in standard 4.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). The fourth-grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed. ~~It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in this strand.~~

4.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) distinctions are made among observations, conclusions, inferences, and predictions;
b) objects or events are classified and arranged according to characteristics or properties;
c) appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units;
d) appropriate instruments are selected and used to measure elapsed time;
e) predictions and inferences are made, and conclusions are drawn based on data from a variety of sources;
f) independent and dependent variables are identified;
g) constants in an experimental situation are identified;
h) hypotheses are developed as cause and effect relationships;
i) data are collected, recorded, analyzed, and displayed using bar and basic line graphs;
j) numerical data that are contradictory or unusual in experimental results are recognized;
k) data are communicated with simple graphs, pictures, written statements, and numbers;
l) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
m) current applications are used to reinforce science concepts.

~~Understanding the Standard~~ Overview

The skills described in standard 4.1 are intended to define the "investigate" component of all of the other fourth-grade standards (4.2–4.8). The intent of standard 4.1 is that students will continue to develop a range of inquiry skills, ~~and~~ achieve proficiency with those skills in the context of the concepts developed at the fourth-grade level, and strengthen their understanding of the nature of science. **Standard 4.1 does not require a discrete unit be taught on scientific investigation and the nature of science because the ~~inquiry~~ skills that make up the standard should be incorporated in all the other fourth-grade standards.** It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science as well as more fully grasp the content-related concepts.

4.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) distinctions are made among observations, conclusions, inferences, and predictions;
b) objects or events are classified and arranged according to characteristics or properties;
c) appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units;
d) appropriate instruments are selected and used to measure elapsed time;
e) predictions and inferences are made, and conclusions are drawn based on data from a variety of sources;
f) independent and dependent variables are identified;
g) constants in an experimental situation are identified;
h) hypotheses are developed as cause and effect relationships;
i) data are collected, recorded, analyzed, and displayed using bar and basic line graphs;
j) numerical data that are contradictory or unusual in experimental results are recognized;
k) data are communicated with simple graphs, pictures, written statements, and numbers;
l) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
m) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard

(Background Information for Instructor Use Only)

~~The concepts developed in this standard include the following:~~

- The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts:
  a) the natural world is understandable;
  b) science is based on evidence, both observational and experimental;
  c) science is a blend of logic and innovation;
  d) scientific ideas are durable yet subject to change as new data are collected;
  e) science is a complex social endeavor; and
  f) scientists try to remain objective and engage in peer review to help avoid bias.

  In grade four, an emphasis should be placed on concepts a, b, c, d, and e.
- Science assumes that the natural world is understandable. Scientific inquiry can provide explanations about nature. This expands students' ~~knowledge~~ thinking from just a knowledge of facts to understanding ~~why~~ how ~~the~~ facts are relevant to everyday life.

Essential Knowledge, Skills, and Processes

In order to meet this standard, it is expected that students ~~should be able to~~ will

- differentiate among simple observations, conclusions, inferences, and predictions, and correctly apply the terminology in oral and written work. ~~This requires students to comprehend the basic terminology and apply it in novel situations related to fourth grade SOL concepts.~~
- analyze a set of 20 or fewer objects~~, measures,~~ or pictures~~;~~, ~~classify~~ Sort them into ~~basic~~ categories to organize the data (~~descriptive or numerical~~ qualitative or quantitative); and construct bar graphs and line graphs depicting the distribution of those data based on characteristics or properties.
- use millimeters, centimeters, meters, kilometers, grams, kilograms, milliliters, liters, ~~grams, and kilograms~~ and degrees Celsius in measurement.
- choose the appropriate instruments, including centimeter rulers, meter sticks, scales, balances, graduated cylinders, beakers, ~~scales and balances,~~ and Celsius thermometers, for making basic metric

4.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) distinctions are made among observations, conclusions, inferences, and predictions;
b) objects or events are classified and arranged according to characteristics or properties;
c) appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units;
d) appropriate instruments are selected and used to measure elapsed time;
e) predictions and inferences are made, and conclusions are drawn based on data from a variety of sources;
f) independent and dependent variables are identified;
g) constants in an experimental situation are identified;
h) hypotheses are developed as cause and effect relationships;
i) data are collected, recorded, analyzed, and displayed using bar and basic line graphs;
j) numerical data that are contradictory or unusual in experimental results are recognized;
k) data are communicated with simple graphs, pictures, written statements, and numbers;
l) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
m) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• Science demands evidence. Scientists develop their ideas based on evidence and they change their ideas when new evidence becomes available or the old evidence is viewed in a different way. • Science uses both logic and innovation. Innovation has always been an important part of science. Scientists draw upon their creativity to visualize how nature works, using analogies, metaphors, and mathematics. • Scientific ideas are durable yet subject to change as new data are collected. The main body of scientific knowledge is very stable and grows by being corrected slowly and having its boundaries extended gradually. Scientists themselves accept the notion that scientific knowledge is always open to improvement and can never be declared absolutely certain. New questions arise, new theories are proposed, new instruments are invented, and new techniques are developed. • Science is a complex social endeavor. It is a complex social process for producing knowledge about the natural world. Scientific knowledge represents the current consensus among scientists as to what is the best explanation for phenomena in the natural world. This consensus does	measures. • measure elapsed time using a stopwatch or a clock. • make predictions, inferences, and draw conclusions using a variety of sources such as ~~based on~~ picture graphs, bar graphs, and basic line graphs. • analyze the variables in a simple experiment~~,~~, ~~and decide~~ Identify the independent variable and the dependent variable. Decide which other variable(s) must be held constant (not allowed to change) in order for the investigation to represent a fair test. ~~This requires students to comprehend what "variables" are and to apply that idea in new situations related to fourth grade SOL related concepts. Variables are either manipulated or responding.~~ • create a plausible hypothesis, stated in terms of cause (if) and effect (then), from a set of basic observations that can be tested. ~~This requires a student to comprehend what "cause and effect" is and to be able to apply that idea in new situations. The application should occur in terms of fourth grade SOL related concepts or other concrete situations.~~ Hypotheses ~~should~~ can be stated in terms such as: "If the

4.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) distinctions are made among observations, conclusions, inferences, and predictions;
b) objects or events are classified and arranged according to characteristics or properties;
c) appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units;
d) appropriate instruments are selected and used to measure elapsed time;
e) predictions and inferences are made, and conclusions are drawn based on data from a variety of sources;
f) independent and dependent variables are identified;
g) constants in an experimental situation are identified;
h) hypotheses are developed as cause and effect relationships;
i) data are collected, recorded, analyzed, and displayed using bar and basic line graphs;
j) numerical data that are contradictory or unusual in experimental results are recognized;
k) data are communicated with simple graphs, pictures, written statements, and numbers;
l) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
m) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
not arise automatically, since scientists with different backgrounds from all over the world may interpret the same data differently. To build a consensus, scientists communicate their findings to other scientists and attempt to replicate one another's findings. In order to model the work of professional scientists, it is essential for fourth-grade students to engage in frequent discussions with peers about their understanding of their investigations. • An observation is what you see, feel, taste, hear, or smell. Scientists construct knowledge from observations and inferences, not observations alone. To communicate an observation accurately, one must provide a clear description of exactly what is observed and nothing more. Those conducting investigations need to understand the difference between what is seen and what inferences, conclusions, or interpretations can be drawn from the observation. • An inference is ~~a conclusion~~ a tentative explanation based on ~~evidence about events that have already occurred~~ background knowledge and available data. • Accurate observations and evidence are necessary to draw realistic and plausible conclusions. A conclusion is a summary statement based on	water temperature is increased, then the amount of sugar that can be dissolved in it will increase." • organize and analyze data from a simple experiment. Construct bar graphs and line graphs depicting the data. • judge which, if any, data in a simple set of results (generally 10 or fewer in number) appear to be ~~considerably outside the expected range. Students should be able to determine the significance of unusual data~~ contradictory or unusual. • present results of a simple experiment using graphs, pictures, statements, and numbers. • construct a physical model to clarify an explanation, demonstrate a relationship, or solve a need ~~using information related to fourth-grade SOL concepts~~.

4.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

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b) objects or events are classified and arranged according to characteristics or properties;
c) appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units;
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j) numerical data that are contradictory or unusual in experimental results are recognized;
k) data are communicated with simple graphs, pictures, written statements, and numbers;
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m) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
the results of an investigation. • A scientific prediction ~~is a forecast about~~ tells what may happen in some future situation. It is based on the application of scientific principles and factual information. • ~~When drawing a conclusion, you make a~~ Conclusions are drawn by making judgments after considering all the information you have gathered. Conclusions are based on details and facts. • Systematic investigations require standard measures (metric), consistent and reliable tools, and organized reporting of data. The way the data are displayed can make it easier to uncover important information. This can assist in making reliable scientific forecasts of future events. • Elapsed time is the amount of time that has passed between two given times. (*See Grade Four Mathematics Curriculum Framework, Standard 4.9, page 24.*) • An experiment is a fair test driven by a hypothesis. A fair test is one in which only one variable is compared. • A hypothesis is a prediction about the relationship between variables. A	

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~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
hypothesis is an educated guess/prediction about what will happen based on what you already know and what you have already learned from your research. It must be worded so that it is "testable." • In order to conduct an experiment, one must recognize all of the potential variables or changes that can affect its outcome. • An ~~*manipulated*~~ independent variable is the factor in an experiment that is altered by the experimenter. The independent variable is purposely changed or manipulated. • A ~~*responding*~~ dependent variable is the factor in an experiment that changes as a result of the ~~change applied to the manipulated~~ manipulation of the independent variable. • The constants in an experiment are those things that are purposefully not changed ~~but~~ and remain the same throughout the experiment. • In science, it is important that experiments and the observations recorded are repeatable. There are two different types of data – qualitative and quantitative. Qualitative data deal with descriptions and data that can be observed, but not measured. Quantitative data are data that can be counted or measured and the results can be recorded using numbers.	

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c) appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units;
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~~Overview~~ Understanding the Standard

(Background Information for Instructor Use Only)

Quantitative data can be represented visually in graphs and charts. Quantitative data define whereas qualitative data describe. Quantitative data are more valuable in science because they allow direct comparisons between observations made by different people or at different times.

Example of Qualitative vs. Quantitative Data

Main Street Elementary School Science Club

Qualitative	Quantitative
• Friendly • Like science • Positive about schoolwork	• 10 fourth-grade students and 12 fifth-grade students • 14 girls, 8 boys • 92 percent participated in the divisionwide science fair last year

- It is important for students to apply the science content they have learned to current events and applications ~~to bring realism to their learning~~.

Essential Knowledge, Skills, and Processes

Grade Four
Science Strand

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

4.2	The student will investigate and understand characteristics and interactions of moving objects. Key concepts include a) motion is described by an object's direction and speed; b) changes in motion are related to force and mass; c) friction is a force that opposes motion; and d) moving objects have kinetic energy.

~~Understanding the Standard~~ Overview

This standard is introduced in first-grade and prepares students for a more in-depth study of energy in eighth-grade. This standard focuses on the characteristics of moving objects. Key concepts include the effect of forces, such as friction, on moving objects. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

4.2 The student will investigate and understand characteristics and interactions of moving objects. Key concepts include
a) motion is described by an object's direction and speed;
b) changes in motion are related to force and mass;
c) friction is a force that opposes motion; and
d) moving objects have kinetic energy.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • The position of an object can be described by locating it relative to another object or to the background. • Tracing and measuring an object's position over time can describe its motion. • Speed describes how fast an object is moving. • Energy may exist in two states: kinetic or potential. • Kinetic energy is the energy of motion. • A force is any push or pull that causes an object to move, stop, or change speed or direction. • The greater the force, the greater the change in motion will be. The more massive an object, the less effect a given force will have on the object. • Friction is the resistance to motion created by two objects moving against each other. Friction creates heat. • Unless acted on by a force, objects in motion tend to stay in motion and objects at rest remain at rest.	In order to meet this standard, it is expected that students ~~should be able to~~ will • describe the position of an object. • collect and display in a table and line graph time and position data for a moving object. • explain that speed is a measure of motion. • interpret data to determine if the speed of an object is increasing, decreasing, or remaining the same. • identify the forces that cause an object's motion. • describe the direction of an object's motion: up, down, forward, backward. • infer that objects have kinetic energy. • design an investigation to test the following hypothesis: "If the mass of an object increases, then the force needed to move it will increase." • design an investigation to determine the effect of friction on moving objects. Write a testable hypothesis~~,~~ and identify the dependent variable, the independent variable, and the constants. Conduct a fair test, collect and record the data, analyze the data, and report the results of the data.

4.3	The student will investigate and understand the characteristics of electricity. Key concepts include a) conductors and insulators; b) basic circuits; c) static electricity; d) the ability of electrical energy to be transformed into light and motion, and to produce heat; e) simple electromagnets and magnetism; and f) historical contributions in understanding electricity.

~~Understanding the Standard~~ Overview

This standard focuses on the characteristics of electricity as related to circuits and circuit components, magnetism, static charges, and historical contributions important to the understanding of electricity. As electrical energy is an integral part of modern civilization (e.g., powering our computers; lighting, heating and cooling our homes and businesses; and making the information age possible), it is critical that students begin to understand basic electricity concepts. This standard will be the basis for a more in-depth study in the eighth grade. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

4.3 The student will investigate and understand the characteristics of electricity. Key concepts include
a) conductors and insulators;
b) basic circuits;
c) static electricity;
d) the ability of electrical energy to be transformed into light and motion, and to produce heat;
e) simple electromagnets and magnetism; and
f) historical contributions in understanding electricity.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • A continuous flow of negative charges (electrons) creates an electric current. The pathway taken by an electric current is a circuit. Closed circuits allow the movement of electrical energy. Open circuits prevent the movement of electrical energy. • Electrical energy moves through materials that are conductors (metals). Insulators (rubber, plastic, wood) do not conduct electricity well. • Among conducting materials, ~~energy passes more or less easily because of the material's resistance~~ the rate at which energy flows depends on the material's resistance. • In a series circuit, there is only one pathway for the current, but in a parallel circuit there are two or more pathways for it. • Rubbing certain materials together creates static electricity. • Lightning is the discharge of static electricity in the atmosphere. • Electrical energy can be transformed into ~~heat,~~ light~~,~~ or motion, and ~~to~~ can produce ~~heat~~ thermal energy ~~mechanical energy~~. • Certain iron-bearing metals attract other such metals (also nickel and cobalt). • Lines of force extend from the poles of a magnet in an arched pattern defining the area over which magnetic force is exerted. • An electric current creates a magnetic field, and a moving magnetic field	In order to meet this standard, it is expected that students ~~should be able to~~ will • apply the terms insulators, conductors, open and closed in describing electrical circuits. • differentiate between an open and closed electric circuit. • use the dry cell symbols (–) and (+). • create and diagram a functioning series circuit using dry cells, wires, switches, bulbs, and bulb holders. • create and diagram a functioning parallel circuit using dry cells, wires, switches, bulbs, and bulb holders. • differentiate between a parallel and series circuit. • describe the types of energies (i.e., ~~light, heat, motion~~ thermal, radiant, and mechanical) that are transformed by various household appliances (e.g., lamp, toaster, fan). • create a diagram of a magnetic field using a magnet. • compare and contrast a permanent magnet and an electromagnet. • explain how electricity is generated by a moving magnetic field. • design an investigation using static electricity to attract or repel a variety of materials. • explain how static electricity is created and occurs in nature.

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b) basic circuits;
c) static electricity;
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e) simple electromagnets and magnetism; and
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~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
creates an electric current. • A current flowing through a wire creates a magnetic field. Wrapping a wire around certain iron-bearing metals (iron nail) and creating a closed circuit is an example of a simple electromagnet. • Benjamin Franklin, Michael Faraday, and Thomas Edison made important discoveries about electricity.	• construct a simple electromagnet using a wire, nail, or other iron-bearing object, and a dry cell. • design and perform an investigation to determine the strength of an electromagnet. (The ~~manipulated~~ independent variable could be the number of coils of wire and the ~~responding~~ dependent variable could be the number of paperclips the magnet can attract.) • describe the contributions of Ben Franklin, Michael Faraday, and Thomas Edison to the understanding and harnessing of electricity.

Grade Four
Science Strand

Life Processes

This strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards K.6, K.7, 1.4, 1.5, 2.4, 3.4, and 4.4.

4.4	The student will investigate and understand basic plant anatomy and life processes. Key concepts include a) the structures of typical plants and the function of each structure; b) processes and structures involved with plant reproduction; c) photosynthesis; and d) adaptations allow plants to satisfy life needs and respond to the environment.

~~Understanding the Standard~~ Overview

This standard focuses on the basic life processes and anatomy of plants. It represents a more in-depth treatment of the plant structures and the processes associated with plant reproduction. Photosynthesis is introduced in this standard. Closely related standards from previous grades include K.6, 1.4, and 2.4. This standard also is closely connected with concepts presented in science standard 4.5. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

4.4 The student will investigate and understand basic plant anatomy and life processes. Key concepts include
a) the structures of typical plants and the function of each structure;
b) processes and structures involved with plant reproduction;
c) photosynthesis; and
d) adaptations allow plants to satisfy life needs and respond to the environment.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • For many typical green plants, there are anatomical structures that perform certain basic functions. For example, roots anchor the plants and take water and nutrients from the soil. Plant stems provide support and allow movement of water and nutrients. • ~~The plant kingdom~~ Plants can be divided into two general groups: those that produce seeds and those that produce spores. • Many seed-producing plants have roots, stems, leaves, and flowers. • Seeds vary considerably in size. Orchids, for example, produce seeds as small as dust particles. The coconut is one of the largest seeds in the plant kingdom. In many seeds, the protective outer seed coat is resistant to physical damage and may also contain waxes and oils that help prevent water loss. • The embryo within the seed begins as a single cell, the zygote. The basic organs of the plant body can be found in the embryo. In some seeds the embryonic leaves are quite large, filling most of the volume of the seed. The embryonic leaves are a major source of stored food for the embryo. Beans are an example of plants with large embryonic leaves. In many other plants the embryonic leaves are relatively small, and the embryo is nourished by a tissue called endosperm. • Pollination is part of the reproductive process of flowering plants. Pollination is the process by which pollen is transferred from the stamens to the stigma. • The stamen and pistil are reproductive parts of the flower. The sepals are the small leaves that form the housing of the developing flower.	In order to meet this standard, it is expected that students ~~should be able to~~ will • analyze a common plant: identify the roots, stems, leaves, and flowers, and explain the function of each. • create a model/diagram illustrating the parts of a flower and its reproductive processes. ~~e~~Explain your model/diagram using the following terminology: pollination, ~~(~~stamen, stigma, pistil, sepal, embryo, spore, ~~ovary, ovuole,~~ seed~~)~~. • ~~create a model/diagram illustrating the reproductive processes in typical flowering plants, and explain the processes.~~ • compare and contrast different ways plants are pollinated. • explain that ferns and mosses reproduce with spores rather than seeds. • explain the process of photosynthesis, using the following terminology: sunlight, chlorophyll, water, carbon dioxide, oxygen, and sugar. • ~~design an investigation to determine the relationship between the presence of sunlight and plant growth.~~ • explain the role of ~~dormancy for~~ adaptations of common plants to include dormancy, response to light, and response to moisture.

4.4 The student will investigate and understand basic plant anatomy and life processes. Key concepts include a) the structures of typical plants and the function of each structure; b) processes and structures involved with plant reproduction; c) photosynthesis; and d) adaptations allow plants to satisfy life needs and respond to the environment.	
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
• Some plants reproduce with spores. These include ferns and mosses. • Green plants produce their own food through the process of photosynthesis. Green plants use chlorophyll to produce food (sugar), using carbon dioxide, water, ~~nutrients~~ enzymes and other chemicals, and sunlight. Leaves are the primary food producing part of these plants. • Oxygen is ~~produced~~ released during photosynthesis. • Plants adapt to changes in their environment in order to survive. Dormancy is a plant adaptation. Dormancy is a period of suspended life processes brought on by changes in the environment.	

Grade Four
Science Strand

Living Systems

This strand begins in second grade and builds from basic to more complex understandings of a system, both at the ecosystem level and at the level of the cell. The concept of kingdoms of living things and a general classifying of organisms are also presented. The other major topics developed in the strand include the types of relationships among organisms in a food chain, different types of environments and the organisms they support, and the relationship between organisms and their nonliving environment. This strand includes science standards 2.5, 3.5, 3.6, 4.5, 5.5, and 6.7.

4.5	The student will investigate and understand how plants and animals, including humans, in an ecosystem interact with one another and with the nonliving components in the ecosystem. Key concepts include a) plant and animal adaptations; b) organization of populations, communities, and ecosystems and how they interrelate; c) flow of energy through food webs; d) habitats and niches; e) changes in an organism's niche at various stages in its life cycle; and f) influences of human activity on ecosystems.

~~Understanding the Standard~~ Overview

This standard focuses on the relationships among plants, animals, and the nonliving environment and brings together several elements of both Life Processes and Living Systems. This standard assumes students have a basic understanding that all living ~~things~~ organisms are interrelated and dependent in some way on other living ~~things~~ organisms and their environment. Plants and animals in ecological systems live in a web of interdependence in which each species contributes to the functioning of the overall system. Organisms live in a habitat to which they are structurally and behaviorally adapted. Certain conditions within environments determine which organisms and communities succeed there. This standard builds upon previous standards 1.5, 2.4, 2.5. 3.4, 3.5 and 3.6. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

4.5 The student will investigate and understand how plants and animals, including humans, in an ecosystem interact with one another and with the nonliving components in the ecosystem. Key concepts include

a) plant and animal adaptations;
b) organization of populations, communities, and ecosystems and how they interrelate;
c) flow of energy through food webs;
d) habitats and niches;
e) changes in an organism's niche at various stages in its life cycle; and
f) influences of human activity on ecosystems.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Organisms have structural adaptations, or physical attributes, that help them meet a life need. • Organisms also have behavioral adaptations, or certain types of activities they perform, which help them meet a life need. • All the organisms of the same species that live in the same place at the same time are a population. • Populations of species that live in the same place at the same time together make up a community. • The organization of communities is based on the utilization of the energy from the sun within a given ecosystem. The greatest amount of energy in a community is in the producers. • Within a community, organisms are dependent on the survival of other organisms. Energy is passed from one organism to another. • All the populations and the nonliving components in an environment that interact with each other form an ecosystem. • The sun's energy cycles through ecosystems from producers through consumers and back into the nutrient pool through decomposers. • A habitat is the place or kind of place in which an animal or plant naturally lives. An organism's habitat provides food, water, shelter, and space. The size of the habitat depends on the organism's needs.	In order to meet this standard, it is expected that students ~~should be able to~~ will • distinguish between structural (physical) and behavioral adaptations. • investigate and infer the function of basic adaptations ~~and provide evidence for the conclusion~~. • understand that adaptations allow an organism to succeed in a given environment. • explain how different organisms use their unique adaptations to meet their needs. • describe why certain communities exist in given habitats. • illustrate the food webs in a local area. • ~~and~~ compare and contrast the niches of several different organisms within the community. • compare and contrast the differing ways an organism interacts with its surroundings at various stages of its life cycle. Specific examples include a frog and a butterfly. • differentiate among positive and negative influences of human activity on ecosystems.

4.5	The student will investigate and understand how plants and animals, including humans, in an ecosystem interact with one another and with the nonliving components in the ecosystem. Key concepts include a) plant and animal adaptations; b) organization of populations, communities, and ecosystems and how they interrelate; c) flow of energy through food webs; d) habitats and niches; e) changes in an organism's niche at various stages in its life cycle; and f) influences of human activity on ecosystems.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• A niche is the function that an organism performs in the food web of that community. A niche also includes everything else the organism does and needs in its environment. No two types of organisms occupy exactly the same niche in a community. • The organization of a community is defined by the interrelated niches within it. • During its life cycle, an organism's role in the community — its niche — may change. For example, what an animal eats, what eats it, and other relationships will change. • Humans can have a major impact on ecosystems.	

Grade Four
Science Strand

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of how Earth systems are connected and how ~~the~~ Earth interacts with other members of the solar system. The topics developed include shadows; relationships between the sun and ~~the~~ Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards ~~K.7~~ K.8, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

4.6	The student will investigate and understand how weather conditions and phenomena occur and can be predicted. Key concepts include a) weather phenomena; b) weather measurements and meteorological tools; and c) use of weather measurements and weather phenomena to make weather predictions.

~~Understanding the Standard~~ Overview

This standard focuses on weather conditions and a more technical understanding of the tools and methods used to forecast future atmospheric conditions. Weather is introduced in science standard 2.6. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

4.6 The student will investigate and understand how weather conditions and phenomena occur and can be predicted. Key concepts include
a) weather phenomena;
b) weather measurements and meteorological tools; and
c) use of weather measurements and weather phenomena to make weather predictions.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Temperature is the measure of the amount of ~~heat~~ thermal energy in the atmosphere. • Air pressure is due to the weight of the air and is determined by several factors including the temperature of the air. • A front is the boundary between air masses of different temperature and humidity. • Cirrus, stratus, cumulus, and cumulo-nimbus clouds are associated with certain weather conditions. • Cumulus clouds are fluffy and white with flat bottoms. They usually indicate fair weather. However, when they get larger and darker on the bottom, they ~~produce thunderstorms~~ become cumulo-nimbus clouds. Cumulo-nimbus clouds may produce thunderstorms. • Stratus clouds are smooth, gray clouds that cover the whole sky (block out direct sunlight). Light rain and drizzle are usually associated with stratus clouds. • Cirrus clouds are feathery clouds. They are associated with fair weather. Cirrus clouds often indicate that rain or snow will fall within several hours. • Extreme atmospheric conditions create various kinds of storms such as thunderstorms, hurricanes, and tornadoes. • Different atmospheric conditions create different types of precipitation. • Meteorologists gather data by using a variety of instruments. • Meteorologists use data to predict weather patterns.	In order to meet this standard, it is expected that students ~~should be able to~~ will • ~~use a thermometer~~ design an investigation in which a thermometer is used to compare air temperatures over a period of time. • analyze the changes in air pressure occurring over time, using a barometer, and predict what the changes mean in terms of changing weather patterns. • illustrate and label high and low pressures on a map. • differentiate between the types of weather associated with high and low pressure air masses. Illustrate and label high and low pressure air masses and warm and cold fronts. • differentiate between cloud types (i.e., cirrus, stratus, cumulus, and cumulo-nimbus clouds) and the associated weather. • compare and contrast the formation of different types of precipitation (e.g., rain, snow, sleet, and hail). • recognize a variety of storm types, describe the weather conditions associated with each, and explain when they occur (e.g., thunderstorms, hurricanes, and tornadoes). • analyze and report information about temperature and precipitation on weather maps. • measure wind speed, using an anemometer. • measure precipitation with a rain gauge. • design an investigation in which weather data are gathered using meteorological tools and charted to make weather predictions.

4.6	The student will investigate and understand how weather conditions and phenomena occur and can be predicted. Key concepts include a) weather phenomena; b) weather measurements and meteorological tools; and c) use of weather measurements and weather phenomena to make weather predictions.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• A barometer measures air pressure. • An anemometer measures wind speed. • A rain gauge measures the amount of precipitation. • A thermometer measures the temperature of the air.	

Grade Four
Science Strand

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living things. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, our solar system, and change in ~~the~~ Earth's surface over time. This strand includes science standards ~~K.8,~~ K.9, K.10, 1.7, 2.7, 3.8, 3.9, 4.7, 4.8, and 5.7.

4.7	The student will investigate and understand the organization of the solar system. Key concepts include a) the planets in the solar system; b) the order of the planets in the solar system; and c) the relative sizes of the planets.

~~Understanding the Standard~~ Overview

This standard focuses on providing an introduction to our solar system. This includes the introduction to the planets in the solar system, their order in the solar system in relation to the sun, and the sizes of the planets in relation to the size of Earth. A more in-depth study of the solar system is in standard 6.8. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

4.7 The student will investigate and understand the organization of the solar system. Key concepts include
a) the planets in the solar system;
b) the order of the planets in the solar system; and
c) the relative sizes of the planets.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Our solar system is ancient. Early astronomers believed that Earth was the center of the universe and all other heavenly bodies orbited around Earth. We now know that our sun is the center of our solar system and eight planets, a handful of dwarf planets, 170 named moons, dust, gas, and thousands of asteroids and comets orbit around the sun. • Our solar system is made up of eight planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. • Mercury, Venus, Earth, and Mars are considered terrestrial planets. Jupiter, Saturn, Uranus, and Neptune are called gas giants. • Mercury is closest to the sun and is a small, heavily cratered planet. Mercury looks like our moon. Since Pluto's ~~downgrade~~ reclassification from planet to dwarf planet, Mercury is now the smallest planet in our solar system. • Venus is second from the sun. It is similar to Earth in size and mass, and has a permanent blanket of clouds that trap so much heat that the temperatures on the surface of Venus are hot enough to melt lead. • Earth is third from the sun. Earth's atmosphere, the liquid water found on Earth, and its distance from the sun, among many other factors, make Earth a haven for life. • Mars is fourth from the sun. ~~Mars'~~ The atmosphere on Mars is thin and there is a vast network of canyons and riverbeds on the red planet. Scientists hypothesize that Mars once supported a wet, warm Earth-like climate. • Jupiter is fifth from the sun. Jupiter is the largest planet in the solar	In order to meet this standard, it is expected that students ~~should be able to~~ will • name the eight planets and describe whether they are a terrestrial planet or a gas giant. • sequence the eight planets in the solar system based on their position from the sun. (Mercury is the first from the sun, Venus is the second, etc.) • sequence the eight planets in the solar system based on size (Jupiter is the largest, Saturn is next, etc.) • construct a simple model of the sun and the planets in our solar system.

4.7 The student will investigate and understand the organization of the solar system. Key concepts include
a) the planets in the solar system;
b) the order of the planets in the solar system; and
c) the relative sizes of the planets.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
system and is considered a gas giant. Jupiter has no solid surface. • Saturn is sixth from the sun. ~~Ancient~~ Early scientists thought Saturn was the only planet with rings, but we now know that all four gas giants (Jupiter, Saturn, Uranus, and Neptune) have rings. • Uranus is seventh from the sun. Uranus is a gas giant. • Neptune is eighth from the sun. Neptune appears blue through telescopes and is a gas giant. • The eight planets sorted by size from largest to smallest are: Jupiter, Saturn, Uranus, Neptune, Earth, Venus, Mars, and Mercury. • Pluto is no longer included in the list of planets in our solar system due to its small size and irregular orbit. Many astronomers questioned whether Pluto should be grouped with worlds like Earth and Jupiter. In 2006, this debate led the International Astronomical Union (IAU), the recognized authority in naming heavenly objects, to formally reclassify Pluto. On August 24, 2006, Pluto's status was officially changed from planet to dwarf planet. • A new distinct class of objects called "dwarf planets" was identified in 2006. It was agreed that "planets" and "dwarf planets" are two distinct classes of objects. The first members of the dwarf planet category are Ceres, Pluto and 2003 UB313, given the name Eris. More dwarf planets are expected to be announced by the IAU in the future. • What differentiates a dwarf planet from a planet? For the most part, they are identical, but there is one key difference: A dwarf planet has not "cleared the neighborhood" around its orbit, which means it has not become gravitationally dominant and it shares its orbital space with other bodies of a similar size. • Pluto is smaller than seven of the moons in our solar system and cannot	

4.7 The student will investigate and understand the organization of the solar system. Key concepts include a) the planets in the solar system; b) the order of the planets in the solar system; and c) the relative sizes of the planets.	
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
be seen without a telescope.	

4.8	The student will investigate and understand the relationships among Earth, the moon, and the sun. Key concepts include a) the motions of Earth, the moon, and the sun; b) the causes for Earth's seasons; c) the causes for the phases of the moon; d) the relative size, position, age, and makeup of Earth, the moon, and the sun; and e) historical contributions in understanding the Earth-moon-sun system.

~~Understanding the Standard~~ Overview

This standard focuses on the Earth-moon-sun system and includes knowledge related to the motions of this system and the results of our unique position in it. This includes the presence of an atmosphere, liquid water, and life. The standard is built on concepts developed in science standards ~~K.7~~ K.8, 1.6, and 3.8 and that will be further expanded in 6.8. A more in-depth study of ~~the~~ Earth's makeup is in standard 5.7. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

Standard 4.8

4.8 The student will investigate and understand the relationships among Earth, the moon, and the sun. Key concepts include

a) the motions of Earth, the moon, and the sun;
b) the causes for Earth's seasons;
c) the causes for the phases of the moon;
d) the relative size, position, age, and makeup of Earth, the moon, and the sun; and
e) historical contributions in understanding the Earth-moon-sun system.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • ~~The~~ Earth completes one revolution around the sun every 365 ¼ days. The moon revolves around ~~the~~ Earth about once every month. • Due to its axial tilt, ~~the~~ Earth experiences seasons during its revolution around the sun. • The phases of the moon are caused by its position relative to ~~the~~ Earth and the sun. The phases of the moon include the new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, last (third) quarter, and waning crescent. • The sun is an average-sized yellow star, about 110 times the diameter of ~~the~~ Earth. The sun is approximately 4.6 billion years old. • Our moon is a small rocky satellite, having about one-quarter the diameter of ~~the~~ Earth and one-eightieth its mass. It has extremes of temperature, virtually no atmosphere~~, no water, and no~~ or life, and very little water. • ~~The~~ Earth is one of ~~nine~~ eight planets that revolve around the sun and comprise the solar system. ~~The~~ Earth, the third planet from the sun, is one of the four ~~rocky~~ terrestrial inner planets. It is about 150 million kilometers from the sun. ~~(The emphasis is placed on the Earth, rather than the other planets.)~~ • ~~The~~ Earth is a geologically active planet with a surface that is constantly changing. Unlike the other three inner planets (see previous bullet), it	In order to meet this standard, it is expected that students ~~should be able to~~ will • differentiate between rotation and revolution. • describe how ~~the~~ Earth's axial tilt causes the seasons. • model the formation of the eight moon phases, sequence the phases in order, and describe how the phases occur. • describe the major characteristics of the sun, including its approximate size, color, age, and overall composition. • create and describe a model of the Earth-moon-sun system with approximate scale distances and sizes. • compare and contrast the surface conditions of ~~the~~ Earth, the moon, and the sun. • compare and contrast an Earth-centered to the sun-centered model of the solar system. • analyze the differences in what Aristotle, Ptolemy, Copernicus, and Galileo observed and what influenced their conclusions. • describe a contribution of the NASA Apollo missions to our understanding of the moon.

Standard 4.8

4.8 The student will investigate and understand the relationships among Earth, the moon, and the sun. Key concepts include

a) the motions of Earth, the moon, and the sun;
b) the causes for Earth's seasons;
c) the causes for the phases of the moon;
d) the relative size, position, age, and makeup of Earth, the moon, and the sun; and
e) historical contributions in understanding the Earth-moon-sun system.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
has large amounts of life-supporting water and an oxygen-rich atmosphere. ~~The~~ Earth's protective atmosphere blocks out most of the sun's damaging rays. • Our understanding of the solar system has changed from an Earth-centered model of Aristotle and Ptolemy to the sun-centered model of Copernicus and Galileo. • The NASA Apollo missions added greatly to our understanding of the moon. • Our understanding of the sun, moon, and the solar system continues to change with new scientific discoveries.	

Earth Resources

This strand focuses on student understanding the role of resources in the natural world and how people can utilize those resources in a sustainable way. An important idea represented in this strand is the concept of management of resource use. This begins with basic ideas of conservation and proceeds to more abstract consideration of costs and benefits. The topics developed include conservation of materials, soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards ~~K.10,~~ K.11, 1.8, 2.8, 3.10, 3.11, ~~4.8,~~ 4.9, and 6.9.

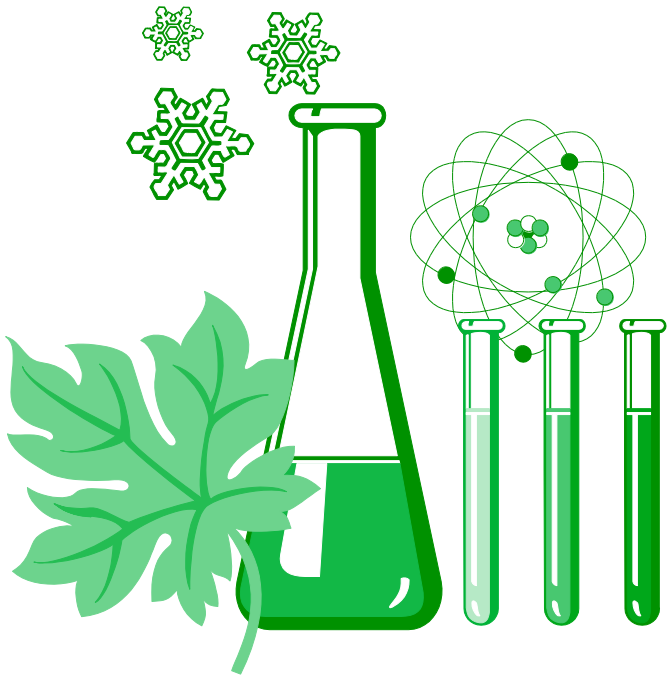
4.9	The student will investigate and understand important Virginia natural resources. Key concepts include a) watersheds and water resources; b) animals and plants; c) minerals, rocks, ores, and energy sources; and d) forests, soil, and land.

~~Understanding the Standard~~ Overview

Virginia has a rich variety of natural resources. These provide the raw materials for our daily lives and sustain our economy. Natural resources are finite and must be used wisely to ~~insure~~ ensure their continued availability. This concept of natural resources is introduced in 1.8 and extended in 6.9. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

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

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Virginia is rich in a wide variety of natural resources, including forests, arable (farmable) land, coal, sand and aggregates (rocks), wildlife and aquatic organisms, clean water and air, and beautiful scenery. • A watershed is an area over which surface water (and the materials it carries) flows to a single collection place. The Chesapeake Bay watershed covers approximately half of Virginia's land area. The other two major watershed systems are the Gulf of Mexico and the North Carolina Sounds. • Virginia's water resources include groundwater, lakes, reservoirs, rivers, bays, and the Atlantic Ocean. • Virginia has a great variety of plant and animal resources. • Natural and cultivated forests are a widespread resource in Virginia. • Virginia's soil and land support a great variety of life, provide space for many economic activities, and offer a variety of recreational opportunities.	In order to meet this standard, it is expected that students ~~should be able to~~ will • compare and contrast natural and ~~man-made~~ human-made resources. • distinguish among rivers, lakes, and bays; describe characteristics of each; and name an example of each in Virginia. • create and interpret a model of a watershed. Evaluate the statement: "We all live downstream." • identify watershed addresses. • recognize the importance of Virginia's mineral resources, including coal, limestone, granite, and sand and gravel. • appraise the importance of natural and cultivated forests in Virginia. • describe a variety of soil and land uses important in Virginia.



Science Standards of Learning Curriculum Framework

Grade Five

Final Review
November 18, 2010

Commonwealth of Virginia
Board of Education
Richmond, Virginia
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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Grade Five
Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student ~~should~~ will be able to do when conducting activities and investigations, and represents the student understanding of the nature of science. The various skill categories are described in the "Investigate and Understand" section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 5.1 represent more specifically what a student should be able to do as a result of science experiences in fifth grade. Across the grade levels, the skills in the "Scientific Investigation, Reasoning, and Logic" strand form a nearly continuous sequence of investigative skills and an understanding of the nature of science. ~~(Please note Appendix, "Science Skills, Scope, & Sequence.")~~ It is important that the classroom teacher understand~~s~~ how the skills in standard 5.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). The fifth-grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed. ~~It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in the "Scientific Investigation, Reasoning, and Logic" strand.~~

5.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) items such as rocks, minerals, and organisms are identified using various classification keys;
b) estimates are made and accurate measurements of length, mass, volume, and temperature are made in metric units using proper tools;
c) estimates are made and accurate measurements of elapsed time are made using proper tools;
d) hypotheses are formed from testable questions;
e) independent and dependent variables are identified;
f) constants in an experimental situation are identified;
g) data are collected, recorded, analyzed, and communicated using proper graphical representations and metric measurements;
h) predictions are made using patterns from data collected, and simple graphical data are generated;
i) inferences are made and conclusions are drawn;
j) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
k) current applications are used to reinforce science concepts.

~~Understanding the Standard~~ Overview

The skills in standard 5.1 are intended to define the "investigate" component and the understanding of the nature of science ~~of~~ for all of the other fifth-grade standards (5.2–5.7). The intent of standard 5.1 is for students to continue to develop a range of inquiry skills, ~~and~~ achieve proficiency with those skills, and develop and reinforce their understanding of the nature of science in the context of the concepts developed at the fifth-grade level. **Standard 5.1 does not require a discrete unit be taught on scientific investigation because the ~~inquiry~~ skills that make up the standard should be incorporated in all the other fifth-grade standards.** It is also intended that by developing these skills, students will achieve a greater understanding of scientific inquiry and the nature of science and will more fully grasp the content-related concepts.

5.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) items such as rocks, minerals, and organisms are identified using various classification keys;
b) estimates are made and accurate measurements of length, mass, volume, and temperature are made in metric units using proper tools;
c) estimates are made and accurate measurements of elapsed time are made using proper tools;
d) hypotheses are formed from testable questions;
e) independent and dependent variables are identified;
f) constants in an experimental situation are identified;
g) data are collected, recorded, analyzed, and communicated using proper graphical representations and metric measurements;
h) predictions are made using patterns from data collected, and simple graphical data are generated;
i) inferences are made and conclusions are drawn;
j) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
k) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts: a) the natural world is understandable; b) science is based on evidence, both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. In grade five, an emphasis should be placed on concepts a, b, c, d, and e. • Science assumes that the natural world is understandable. Scientific inquiry can provide explanations about nature. This expands students' ~~knowledge~~ thinking from just a knowledge of facts to understanding ~~why~~ how ~~the~~ facts are relevant to everyday life. • Science demands evidence. Scientists develop their ideas based on	In order to meet this standard, it is expected that students ~~should be able to~~ will • use classification keys to identify rocks, minerals, and organisms. • select and use the appropriate instruments, including centimeter rulers, meter sticks, graduated cylinders, balances, stopwatches, and thermometers for making basic measurements. • make ~~plausible~~ reasonable estimations of length, mass, ~~and~~ volume, and elapsed time. • measure ~~temperature,~~ length, mass, ~~and~~ volume, and temperature using metric measures. This includes millimeters, centimeters, meters, kilometers, grams, kilograms, milliliters, liters, and degrees Celsius. • use a testable question to form a hypothesis as a~~n~~ cause and effect (e.g., "if…, then…") statement. • analyze the variables in a simple experiment and identify the ~~manipulated (~~independent~~)~~ and ~~responding (~~dependent~~)~~ variables, and the constants. • collect, record, analyze, and report data, using charts and tables, and

5.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) items such as rocks, minerals, and organisms are identified using various classification keys;
b) estimates are made and accurate measurements of length, mass, volume, and temperature are made in metric units using proper tools;
c) estimates are made and accurate measurements of elapsed time are made using proper tools;
d) hypotheses are formed from testable questions;
e) independent and dependent variables are identified;
f) constants in an experimental situation are identified;
g) data are collected, recorded, analyzed, and communicated using proper graphical representations and metric measurements;
h) predictions are made using patterns from data collected, and simple graphical data are generated;
i) inferences are made and conclusions are drawn;
j) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
k) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
evidence and they change their ideas when new evidence becomes available or the old evidence is viewed in a different way. • Science uses both logic and innovation. Innovation has always been an important part of science. Scientists draw upon their creativity to visualize how nature works, using analogies, metaphors, and mathematics. • Scientific ideas are durable yet subject to change as new data are collected. The main body of scientific knowledge is very stable and grows by being corrected slowly and having its boundaries extended gradually. Scientists themselves accept the notion that scientific knowledge is always open to improvement and can never be declared absolutely certain. New questions arise, new theories are proposed, new instruments are invented, and new techniques are developed. • Science is a complex social endeavor. It is a complex social process for producing knowledge about the natural world. Scientific knowledge represents the current consensus among scientists as to what is the best explanation for phenomena in the natural world. This consensus does not arise automatically, since scientists with different backgrounds from all over the world may interpret the same data differently. To build a consensus, scientists communicate their findings to other scientists and attempt to replicate one another's findings. In order to model the work	translate numerical data into bar or line graphs. • make predictions based on trends in data. This requires the recognition of patterns and trends and determination of what those trends may represent. • ~~define/~~make ~~observations and~~ inferences and draw conclusions. • distinguish between ~~observations and~~ inferences and conclusions. • ~~measure, record, identify, collect, and organize observations. Distinguish between qualitative and quantitative observations.~~ • construct a physical model to clarify an explanation, demonstrate a relationship, or solve a need.

5.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) items such as rocks, minerals, and organisms are identified using various classification keys;
b) estimates are made and accurate measurements of length, mass, volume, and temperature are made in metric units using proper tools;
c) estimates are made and accurate measurements of elapsed time are made using proper tools;
d) hypotheses are formed from testable questions;
e) independent and dependent variables are identified;
f) constants in an experimental situation are identified;
g) data are collected, recorded, analyzed, and communicated using proper graphical representations and metric measurements;
h) predictions are made using patterns from data collected, and simple graphical data are generated;
i) inferences are made and conclusions are drawn;
j) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
k) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
of professional scientists, it is essential for fifth-grade students to engage in frequent discussions with peers about their understanding of their investigations. • Systematic investigations require standard measures and consistent and reliable tools. Metric measures are a standard way to make measurements and are recognized around the world. • A classification key is an important tool used to help identify objects and organisms. It consists of a branching set of choices organized in levels, with most levels of the key having two choices. Each level provides more specific descriptors, eventually leading to identification. • A hypothesis is an educated guess/prediction about what will happen based on what you already know and what you have already learned from your research. It must be worded so that it is "testable." The hypothesis should be written as an "If…, then…." statement, such as "If all light is blocked from a plant for two weeks, then the plant will die." • An ~~*manipulated*~~ independent variable is the factor in an experiment that is altered by the experimenter. The independent variable is purposely changed or manipulated. • A ~~*responding*~~ dependent variable is the factor in an experiment that changes as a result of the ~~manipulated changes made to~~ manipulation of	

5.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) items such as rocks, minerals, and organisms are identified using various classification keys;
b) estimates are made and accurate measurements of length, mass, volume, and temperature are made in metric units using proper tools;
c) estimates are made and accurate measurements of elapsed time are made using proper tools;
d) hypotheses are formed from testable questions;
e) independent and dependent variables are identified;
f) constants in an experimental situation are identified;
g) data are collected, recorded, analyzed, and communicated using proper graphical representations and metric measurements;
h) predictions are made using patterns from data collected, and simple graphical data are generated;
i) inferences are made and conclusions are drawn;
j) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
k) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
the independent variable. • The constants in an experiment are those things that are ~~not changed~~ purposefully kept the same throughout the experiment. ~~Constants are all the factors that remain the same throughout the experiment.~~ • When conducting experiments, data are collected, recorded, analyzed, and communicated using proper graphical representations and metric measurements. • Systematic investigations require organized reporting of data. The way the data are displayed can make it easier to see important patterns, trends, and relationships. Bar graphs and line graphs are useful tools for reporting discrete data and continuous data, respectively. • A scientific prediction is a forecast about what may happen in some future situation. It is based on the application of factual information and principles and recognition of trends and patterns. • Estimation is a useful tool for making approximate measures and giving general descriptions. In order to make reliable estimates, one must have experience using the particular unit. • ~~Observation is the use of senses to collect information about the environment.~~ An ~~I~~inference is a tentative explanation based on	

5.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) items such as rocks, minerals, and organisms are identified using various classification keys;
b) estimates are made and accurate measurements of length, mass, volume, and temperature are made in metric units using proper tools;
c) estimates are made and accurate measurements of elapsed time are made using proper tools;
d) hypotheses are formed from testable questions;
e) independent and dependent variables are identified;
f) constants in an experimental situation are identified;
g) data are collected, recorded, analyzed, and communicated using proper graphical representations and metric measurements;
h) predictions are made using patterns from data collected, and simple graphical data are generated;
i) inferences are made and conclusions are drawn;
j) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
k) current applications are used to reinforce science concepts.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
background knowledge and available data. ~~the use of prior knowledge and experience to generate conclusions about those observations.~~ • A conclusion is a summary statement based on the results of an investigation. Scientific conclusions are based ~~both~~ on verifiable observations (science is empirical) ~~and on inferences~~. • Scientific modeling is the process of generating abstract, conceptual, graphical and/or mathematical models. It is an approximation or simulation of a real system that omits all but the most essential variables of the system. In order to create a model, a scientist must first make some assumptions about the essential structure and relationships of objects and/or events in the real world. These assumptions are about what is necessary or important to explain the phenomena. • It is important for students to apply the science content that they have learned to current issues and applications.	

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

5.2	The student will investigate and understand how sound is created and transmitted, and how it is used. Key concepts include a) compression waves; b) vibration, compression, wavelength, frequency, amplitude; c) the ability of different media (solids, liquids, and gases) to transmit sound; and d) uses and applications of sound waves.

~~Understanding the Standard~~ Overview

This standard introduces the concept of what sound is and how sound is transmitted. The students are introduced to scientific vocabulary and the phenomena of compression waves, frequency, waves, wavelength, and vibration in this standard. Students should make predictions about and experiment with the transmission of sound. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

5.2 The student will investigate and understand how sound is created and transmitted, and how it is used. Key concepts include
a) compression waves;
b) vibration, compression, wavelength, frequency, amplitude;
c) the ability of different media (solids, liquids, and gases) to transmit sound; and
d) uses and applications of sound waves.

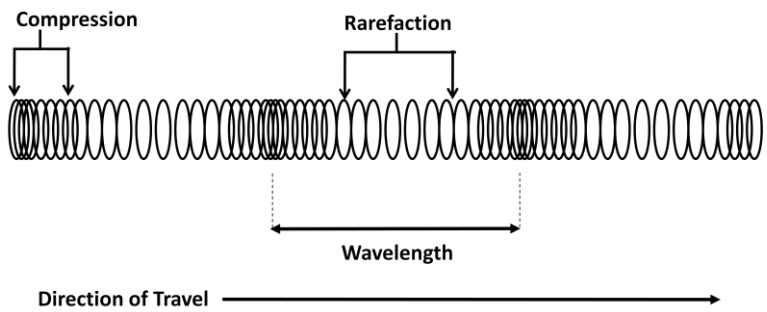
~~Overview~~ Understanding the Standard

(Background Information for Instructor Use Only)

~~The concepts developed in this standard include the following:~~

- Sound is a form of energy produced and transmitted by vibrating matter.
- Sound waves are compression (longitudinal) waves.
- When compression (longitudinal) waves move through matter (solid, liquid, or a gas), the molecules of the matter move backward and forward in the direction in which the wave is traveling. As sound waves travel, molecules are pressed together in some parts (compression) and in some parts are spread out (rarefaction). A child's toy in the form of a coil is a good tool to demonstrate a compression (longitudinal) wave.

Compression (Longitudinal) Wave



- ~~Sound travels in waves and can be described by the wavelength and frequency of the waves. A wave is a disturbance moving through a medium (solid, liquid, or gas).~~

Essential Knowledge, Skills, and Processes

In order to meet this standard, it is expected that students ~~should be able to~~ will

- use the basic terminology of sound to describe what sound is, how it is formed, how it affects matter, and how it travels.
- create and interpret a model or diagram of a compression wave.
- explain why sound waves travel only where there is matter to transmit them.
- explain the relationship between frequency and pitch.
- design an investigation to determine what factors affect the pitch of a vibrating object. This includes vibrating strings, rubber bands, beakers/bottles of air and water, tubes (as in wind chimes), and other common materials.
- compare and contrast sound traveling through a solid with sound traveling through the air. Explain how different media (solid, liquid, and gas) will affect the transmission of sound.
- compare and contrast the sound~~s~~ (voice) that humans make and hear to ~~that~~ those of other animals. This includes bats, dogs, and whales.
- compare and contrast how different kinds of musical instruments make sound. This includes string instruments, woodwinds, percussion instruments, and brass instruments.

5.2 The student will investigate and understand how sound is created and transmitted, and how it is used. Key concepts include

a) compression waves;
b) vibration, compression, wavelength, frequency, amplitude;
c) the ability of different media (solids, liquids, and gases) to transmit sound; and
d) uses and applications of sound waves.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• The frequency of sound is the number of ~~vibrations~~ wavelengths in a given unit of time. • When we talk, sound waves travel in air. Sound also travels in liquids and solids. Sound waves must have a medium ~~in~~ through which to travel. In a vacuum sound cannot travel because there is no matter for it to move through. • ~~Sound is a compression wave moving outward from its source.~~ The wavelength of sound is the distance between two compressions or between two rarefactions. The wavelength can be measured from any point on a wave as long as it is measured to the same point on the next wave. • Pitch is determined by the frequency of a vibrating object. Objects vibrating faster have a higher pitch than objects vibrating slower. A change in frequency of sound waves causes an audible sensation—a difference in pitch. • Amplitude is the amount of energy in a compression (longitudinal) wave and is related to intensity and volume. For example, when a loud sound is heard, it is because many molecules have been vibrated with much force. A soft sound is made with fewer molecules being vibrated with less force. • Sound travels more quickly through solids than through liquids and gases because the molecules of a solid are closer together. Sound travels ~~most slowly~~ the slowest through gases because the molecules of a gas are farthest apart. • Some animals make and hear ranges of sound vibrations different from those that humans can make and hear.	

5.2 The student will investigate and understand how sound is created and transmitted, and how it is used. Key concepts include a) compression waves; b) vibration, compression, wavelength, frequency, amplitude; c) the ability of different media (solids, liquids, and gases) to transmit sound; and d) uses and applications of sound waves.	
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
• Musical instruments vibrate to produce sound. There are many different types of musical instruments and each instrument causes the vibrations in different ways. The most widely accepted way to classify musical instruments is to classify them by the way in which the sound is produced by the instrument. The four basic classifications are percussion instruments (e.g., drums, cymbals), stringed instruments (e.g., violin, piano, guitar), wind instruments (e.g., flute, clarinet, trumpet, trombone), and electronic instruments (e.g., electronic organ, electric guitar).	

5.3	The student will investigate and understand basic characteristics of visible light and how it behaves. Key concepts include a) transverse waves; b) the visible spectrum; c) opaque, transparent, and translucent; d) reflection of light from reflective surfaces; and e) refraction of light through water and prisms.

~~Understanding the Standard~~ Overview

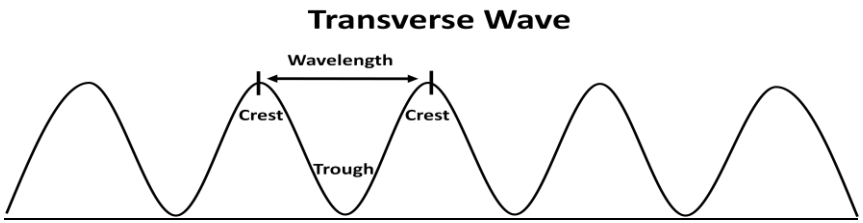
Concepts related to light are introduced at the fifth-grade level. Standard 5.3 focuses on the characteristics of visible light~~,~~ and the tools that aid in the production and use of light~~, and the historical contributions of inventors and scientists~~. Instruction should center on the basic science concerning light energy and how we use light in our daily lives. A related science standard is 4.2, which focuses on forms of energy and provides a foundation for understanding that light is energy. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

5.3 The student will investigate and understand basic characteristics of visible light and how it behaves. Key concepts include
a) transverse waves;
b) the visible spectrum;
c) opaque, transparent, and translucent;
d) reflection of light from reflective surfaces; and
e) refraction of light through water and prisms.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Light has properties of both a wave and a particle. Recent theory identifies light as a small particle, called a photon. A photon moves in a straight line. In both the light wave and photon descriptions, light is energy. • Because light has both electric and magnetic fields, it is referred to as electromagnetic radiation. Light waves ~~are~~ move as transverse waves and travel through a vacuum at a speed of approximately 186,000 miles per second (2.99 x 10^8 meters per second). Compared to sound, light travels extremely fast. It takes light from the sun less than 8½ minutes to travel 93 million miles (150 million kilometers) to reach ~~the~~ Earth. • Unlike sound, light waves travel in straight paths called rays and do not need a medium through which to move. A ray is the straight line that represents the path of light. A beam is a group of parallel rays. • Light waves are characterized by their wavelengths and the frequency of their wavelengths. ~~In the visible spectrum, red has the longest wavelength, and violet has the shortest. Wavelengths get progressively shorter from red to violet.~~ • The size of a wave is measured as its wavelength, which is the distance between any two corresponding points on successive waves, usually crest-to-crest or trough-to-trough. The wavelength can be measured from any point on a wave as long as it is measured to the same point on the next wave.	In order to meet this standard, it is expected that students ~~should be able to~~ will • diagram and label a representation of a light wave, including wavelength, ~~peak,~~ crest, and trough. • explain the relationships between wavelength and the color of light. Name the colors of the visible spectrum. • explain the terms transparent, translucent, and opaque, and give an example of each. • compare and contrast reflection and refraction, using water, prisms, and mirrors. • analyze the effects of a prism on white light and describe why this occurs. Explain ~~why a rainbow occurs~~ the relationship between the refraction of light and the formation of a rainbow.

5.3 The student will investigate and understand basic characteristics of visible light and how it behaves. Key concepts include

a) transverse waves;
b) the visible spectrum;
c) opaque, transparent, and translucent;
d) reflection of light from reflective surfaces; and
e) refraction of light through water and prisms.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
 • Frequency is the number of waves passing a given point every second. The greater the frequency, the greater the amount of energy. • Light waves are waves of energy. The amount of energy in a light wave is proportionally related to its frequency: high frequency light has high energy; low frequency light has low energy. The more wavelengths in a light wave in a given period of time, the higher the energy level. Thus gamma rays have the most energy, and radio waves have the least. Of visible light, violet has the most energy and red the least.	

5.3 The student will investigate and understand basic characteristics of visible light and how it behaves. Key concepts include

a) transverse waves;
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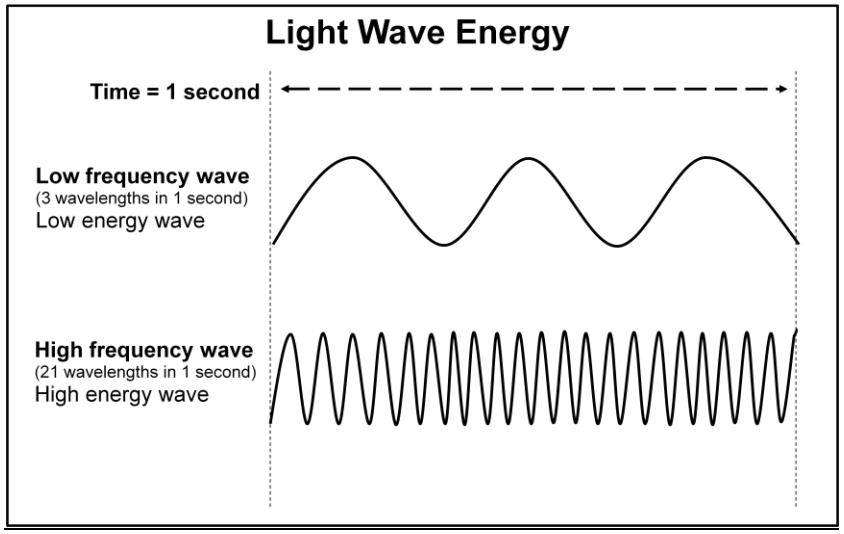
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
 • The entire range of electromagnetic radiation (light) is called the electromagnetic spectrum.	

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a) transverse waves;
b) the visible spectrum;
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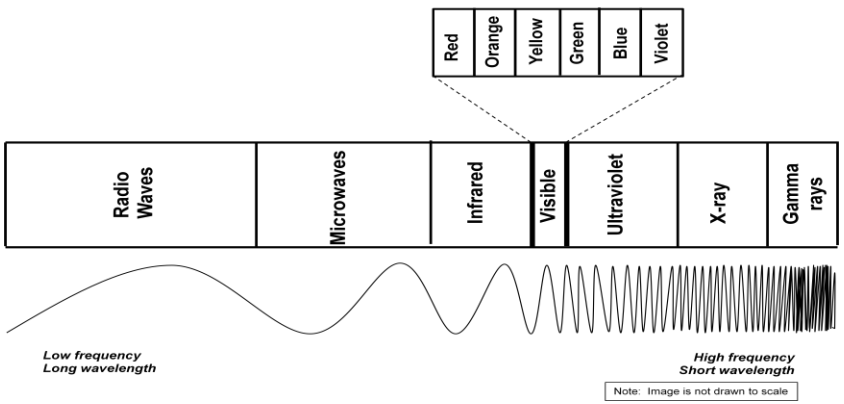
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes

Electromagnetic Spectrum



- The only difference between the various types of electromagnetic radiation is the amount of energy. Sunlight consists of the entire electromagnetic spectrum.
- The wavelengths detectible by the human eye represent only a very small part of the total electromagnetic spectrum. ~~The part of the electromagnetic spectrum that is visible light is a very narrow part.~~
- We see visible light ~~waves~~ as the colors of the rainbow. Each color has a different wavelength. Red has the longest wavelength and violet has the shortest wavelength. The colors of the visible spectrum from the longest wavelength to the shortest wavelength are: red, orange, yellow, green, blue, and violet (ROYGBV). Most scientists no longer include the color

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a) transverse waves;
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~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
indigo, which used to be included between blue and violet. • Black and white are not spectral colors. Black is when a material absorbs all the visible light and no light is reflected back. Black is a total absence of reflected light. White is a reflection of all visible light together. • Light travels in straight paths until it hits an object, where it bounces off (is reflected), is bent (is refracted), passes through the object (is transmitted), or is absorbed as heat. • The term reflected light refers to light waves that are neither transmitted nor absorbed, but are thrown back from the surface of the medium they encounter. If the surface of the medium contacted by the wave is smooth and polished (e.g., a mirror), each reflected wave will be reflected back at the same angle as the incident wave. The wave that strikes the surface of the medium (e.g., a mirror) is called the incident wave, and the one that bounces back is called the reflected wave. • ~~Visible light is a combination of several different wavelengths of light traveling together. These wavelengths are represented by the colors red, orange, yellow, green, blue, indigo, and violet (ROYGBIV).~~ • Refraction means the bending of a wave resulting from a change in its velocity (speed) as it moves from one medium to another (e.g., light moving from the air into water). The frequency of the wave does not change. • The amount of bending of the light wave (refraction) depends on: 1. The density of the material it is entering; 2. The wavelength of the light wave; and 3. The angle at which the original light wave enters the new medium.	

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a) transverse waves;
b) the visible spectrum;
c) opaque, transparent, and translucent;
d) reflection of light from reflective surfaces; and
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~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• Some examples of refraction are when: 1. Refraction causes a setting sun to look flat. 2. A spoon appears to bend when it is immersed in a cup of water. The bending seems to take place at the surface of the water, or exactly at the point where there is a change of density. 3. Shadows on the bottom of a pool are caused because air and water have different densities. 4. A glass prism disperses white light into its individual colors. As visible light exits the prism, it is refracted and separated into a display of colors. • A rainbow is an example of both refraction and reflection. Sunlight is first refracted when it enters the surface of a spherical raindrop, it is then reflected off the back of the raindrop, and once again refracted as it leaves the raindrop. • A prism can be used to refract and disperse visible light. When the different wavelengths of light in visible light pass through a prism, they are bent at different angles (refracted). Dispersion occurs when we see the light separated into a display of colors: ROYGBV. ~~The colors of light we see are red, orange, yellow, green, blue, indigo, and violet.~~ • Dispersion is the separation of light. Dispersion occurs with transparent surfaces that are not parallel to each other, such as a prism or gemstone facets. • Light passes through some materials easily (transparent materials), through some materials partially (translucent materials), and through some not at all (opaque materials). The relative terms transparent, translucent,	

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~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
and opaque indicate the amount of light that passes through an object. 1. Examples of transparent materials include clear glass, clear plastic food wrap, clean water, and air. 2. Examples of translucent materials include wax paper, frosted glass, thin fabrics, some plastics, and thin paper. 3. Examples of opaque materials include metal, wood, bricks, aluminum foil, and thick paper.	

Grade Five
Science Strand

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, ~~states~~ phases of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure ~~of~~ and classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

5.4	The student will investigate and understand that matter is anything that has mass and takes up space; and occurs as a solid, liquid, or gas. Key concepts include a) distinguishing properties of each phase of matter; b) the effect of temperature on the phases of matter; c) atoms and elements; d) molecules and compounds; and e) mixtures including solutions.

~~Understanding the Standard~~ Overview

This standard incorporates various characteristics of matter such as mass, volume, and the effect of ~~heat~~ temperature changes on the three ~~states~~ phases of matter. Instruction should center on the basic structure of matter and how it behaves. This standard builds on standard 3.3, which provides a basis for understanding the structure of matter. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

5.4 The student will investigate and understand that matter is anything that has mass and takes up space; and occurs as a solid, liquid, or gas. Key concepts include

a) distinguishing properties of each phase of matter;
b) the effect of temperature on the phases of matter;
c) atoms and elements;
d) molecules and compounds; and
e) mixtures including solutions.

~~Overview~~ Understanding the Standard

(Background Information for Instructor Use Only)

~~The concepts developed in this standard include the following:~~

- Matter is anything that has mass and volume.
- Mass is the amount of matter in an object. The mass of an object does not change. (Weight of an object changes based on the gravitational pull on it. A person will have the same mass on Earth, Mars, and our moon. However, his or her weight on our moon will be 1/6 of what it is on Earth and will be 1/3 as much on Mars.)
- Matter can exist in several distinct forms which are called phases. The three basic phases of matter generally found on Earth are gas, liquid, and solid. (Though other phases of matter have been identified, these are the phases of matter that fifth-grade students are expected to know.)

Characteristics of Gases, Liquids, and Solids

gas	liquid	solid
Assumes the shape of its container	Assumes the shape of its container	Retains a fixed shape
Assumes the volume of its container – no definite volume	Has a definite volume	Has a definite volume
Compressible (lots of free space between particles)	Not easily compressible (little free space between particles)	Not easily compressible (little free space between particles)
Flows easily (particles can move past one another)	Flows easily (particles can move/slide past one another)	Does not flow easily (rigid-particles cannot move/slide past one another)

Essential Knowledge, Skills, and Processes

In order to meet this standard, it is expected that students ~~should be able to~~ will

- construct and interpret a sequence of models (diagrams) showing the activity of molecules in all three ~~states~~ phases of matter.
- construct and interpret models of atoms~~, elements,~~ and molecules~~, and compounds~~.
- identify substances as being an element or a compound.
- design an investigation to determine how ~~heat~~ a change in temperature affects the ~~states~~ phases of matter (e.g., water). Include in the design ways information will be recorded, what measures will be made, what instruments will be used, and ways the data will be graphed.
- compare and contrast mixtures and solutions~~, elements and compounds, and atoms and molecules~~.

5.4	The student will investigate and understand that matter is anything that has mass and takes up space; and occurs as a solid, liquid, or gas. Key concepts include a) distinguishing properties of each phase of matter; b) the effect of temperature on the phases of matter; c) atoms and elements; d) molecules and compounds; and e) mixtures including solutions.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• As its temperature increases, many kinds of matter change from a solid to a liquid to a gas. As its temperature decreases, that matter changes from a gas to a liquid to a solid. • All matter, regardless of its size, shape, or color, is made of particles (atoms and molecules) that are too small to be seen by the unaided eye. • There are more than 100 known elements that make up all matter. A few of the more familiar elements include: hydrogen (H), oxygen (O), helium (He), carbon (C), sodium (Na), and potassium (K). The smallest part of an element is an atom. • A mixture is a combination of two or more substances that do not lose their identifying characteristics when combined. A solution is a mixture in which one substance dissolves in another. • When two or more elements combine to form a new substance, it is called a compound. There are many different types of compounds because atoms of elements combine in many different ways (and in different whole number ratios) to form different compounds. Examples include water (H_2O) and table salt (NaCl). The smallest part of a compound is a molecule. • Nanotechnology is the study of materials at the molecular (atomic) scale. Items at this scale are so small they are no longer visible with the naked eye. Nanotechnology has shown that the behavior and properties of some substances at the nanoscale (a nanometer is one-billionth of a meter) contradict how they behave and what their properties are at the visible scale. Many products on the market today are already benefiting from nanotechnology such as sunscreens, scratch-resistant coatings, and	

5.4 The student will investigate and understand that matter is anything that has mass and takes up space; and occurs as a solid, liquid, or gas. Key concepts include a) distinguishing properties of each phase of matter; b) the effect of temperature on the phases of matter; c) atoms and elements; d) molecules and compounds; and e) mixtures including solutions.	
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
medical procedures.	

Grade Five
Science Strand

Living Systems

This strand begins in second-grade and builds from basic to more complex understandings of a system, both at the ecosystem level and at the level of the cell. The concept of ~~kingdoms~~ characteristics common to various groups of living ~~things~~ organisms and ~~a~~ general and specific ~~classifying~~ classification of organisms based on the characteristics are also presented. The other major topics developed in the strand include the types of relationships among organisms in a food chain, different types of environments and the organisms they support, and the relationship between organisms and their nonliving environment. This strand includes science standards 2.5, 3.5, 3.6, 4.5, 5.5, and 6.7.

5.5	The student will investigate and understand that organisms are made of one or more cells and have distinguishing characteristics that play a vital role in the organism's ability to survive and thrive in its environment. Key concepts include a) basic cell structures and functions; b) classification of organisms using physical characteristics, body structures, and behavior of the organism; and c) traits of organisms that allow them to survive in their environment.

~~Understanding the Standard~~ Overview

This standard emphasizes the major categories of living ~~things~~ organisms and builds on science standards 2.4 and 4.4. The use of a microscope may be applied to the study of plants, animals, and cells. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

5.5 The student will investigate and understand that organisms are made of one or more cells and have distinguishing characteristics that play a vital role in the organism's ability to survive and thrive in its environment. Key concepts include

a) basic cell structures and functions;
b) classification of organisms using physical characteristics, body structures, and behavior of the organism; and
c) traits of organisms that allow them to survive in their environment.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Living things are made of cells. Cells carry out all life processes. New cells come from existing cells. Cells are too small to be seen with the eye alone. By using a microscope, many parts of a cell can be seen. • Though plant and animal cells are similar, they are also different in shape and in some of their parts. Plant cells tend to be rectangular, while animal cells tend to be spherical or at times irregular. • Organisms that share similar characteristics can be organized into groups in order to help understand similarities and differences. • ~~Living things can be categorized into kingdoms: monerans protists, fungi, plants, and animals.~~ • Plants can be categorized as vascular (having special tissues to transport food and water — for example, trees and flowering plants) and nonvascular (not having tissues to transport food and water — for example, moss, liverworts, and hornworts). Most plants are vascular. • Animals can be categorized as vertebrates (having backbones) or invertebrates (not having backbones).	In order to meet this standard, it is expected that students ~~should be able to~~ will • draw, label, and describe the essential structures and functions of plant and animal cells. For plants, include the nucleus, cell wall, cell membrane, vacuole, chloroplasts, and cytoplasm. For animals, include the nucleus, cell membrane, vacuole, and cytoplasm. • design an investigation to make observations of cells. • compare and contrast plant and animal cells and identify their major parts and functions. • group organisms into categories, using their characteristics: living things (kingdoms), plants (vascular and nonvascular), and animals (vertebrates or invertebrates). Name and describe two common examples of each group. • compare and contrast the distinguishing characteristics of ~~the kingdoms of~~ groups of organisms. • identify and explain traits of organisms that allow them to survive in their environment.

Grade Five
Science Strand

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of how Earth systems are connected and how ~~the~~ Earth interacts with other members of the solar system. The topics developed include shadows; relationships between the sun and ~~the~~ Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards ~~K.7~~ K.8, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

5.6	The student will investigate and understand characteristics of the ocean environment. Key concepts include a) geological characteristics; b) physical characteristics; and c) ecological characteristics.

~~Understanding the Standard~~ Overview

This standard extends the study of ecosystems to the ocean environment. It focuses on the major descriptive characteristics of oceans. Among the concepts are the geological characteristics of the ocean floor, the physical characteristics of ocean water, and the ecological characteristics of communities of marine organisms. Connections can be made to standards 5.2, 5.3, 5.4, 5.5, and 5.7. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

5.6 The student will investigate and understand characteristics of the ocean environment. Key concepts include
a) geological characteristics;
b) physical characteristics; and
c) ecological characteristics.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Oceans cover about 70 percent of the surface of ~~the~~ Earth. • Important features of the ocean floor near the continents are the continental shelf, the continental slope, and the continental rise. These areas are covered with thick layers of sediments (sand, mud, rocks). • The depth of the ocean varies. Ocean trenches are very deep, and the continental shelf is relatively shallow. • Ocean water is a complex mixture of gases (air) and dissolved solids (salts, especially sodium chloride). Marine organisms are dependent on dissolved gases for survival. The salinity of ocean water varies in some places depending on rates of evaporation and amount of runoff from nearby land. • The basic motions of ocean water are the waves, currents, and tides. • Ocean currents, including the Gulf Stream, are caused by wind patterns and the differences in water densities (due to salinity and temperature differences). Ocean currents affect the mixing of ocean waters. This can affect plant and animal populations. Currents also affect navigation routes. • As the depth of ocean water increases, the temperature decreases, the pressure increases, and the amount of light decreases. These factors influence the type of life forms that are present at a given depth. • Plankton are tiny free-floating organisms that live in water. Plankton may be animal-like or plant-like. Animal-like plankton are called zooplankton. Plant-like plankton (phytoplankton) carry out most of the photosynthesis on Earth. Therefore, they provide much of Earth's oxygen. Phytoplankton form the base of the ocean food web. Plankton	In order to meet this standard, it is expected that students ~~should be able to~~ will • ~~explain key terminology related to the ocean environment.~~ • create and interpret a model of the ocean floor and label and describe each of the major features. • research and describe the variation in depths associated with ocean features, including the continental shelf, slope, rise, the abyssal plain, and ocean trenches. • design an investigation (including models and simulations) related to physical characteristics of the ocean environment (depth, salinity, formation of waves, causes of tides, and currents, such as the Gulf Stream). • interpret graphical data related to physical characteristics of the ocean. • explain the formation of ocean currents and describe and locate the Gulf Stream. • design an investigation (including models and simulations) related to ~~biologic characteristics~~ ecological relationships of the ocean environment ~~(ecological relationships)~~. • interpret graphical data related to the ~~biological~~ ecological characteristics of the ocean, such as the number of organisms vs. the depth of the water. • analyze how the physical characteristics (depth, salinity, and temperature) of the ocean affect where marine organism can live.

5.6 The student will investigate and understand characteristics of the ocean environment. Key concepts include a) geological characteristics; b) physical characteristics; and c) ecological characteristics.	
~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
flourish in areas where nutrient-rich water upwells from the deep. ~~Plant-like plankton (phytoplankton) produce much of the Earth's oxygen and serve as the base of the ocean ecosystem. Plankton flourish in areas where nutrient-rich water upwells from the deep. Phytoplankton are eaten by animal-like plankton, swimming organisms, and those things organisms that live on the ocean bottom.~~	• create and interpret a model of a basic marine food web, including floating organisms (plankton), swimming organisms, and organisms living on the ocean ~~bottom~~ floor.

Grade Five
Science Strand

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living things. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, our solar system, and change in ~~the~~ Earth's surface over time. This strand includes science standards ~~K.8,~~ K.9, K.10, 1.7, 2.7, 3.8, 3.9, 4.7, 4.8, and 5.7.

5.7	The student will investigate and understand how Earth's surface is constantly changing. Key concepts include a) identification of rock types; b) the rock cycle and how transformations between rocks occur; c) Earth history and fossil evidence; d) the basic structure of Earth's interior; e) changes in Earth's crust due to plate tectonics; f) weathering, erosion, and deposition; and g) human impact.

~~Understanding the Standard~~ Overview

This standard focuses on the constantly changing nature of ~~the~~ Earth's surface and builds on concepts learned in standards 4.6 and 4.8. Among the important ideas presented in this standard are the rock cycle, fossil evidence of change over time, energy from within ~~the~~ Earth that drives tectonic plate movement, shifting tectonic plates that cause earthquakes and volcanoes, weathering and erosion, and human interaction with ~~the~~ Earth's surface. This standard can be related to several ideas found in science standard 5.6. It is intended that students will actively develop and utilize scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

5.7 The student will investigate and understand how Earth's surface is constantly changing. Key concepts include

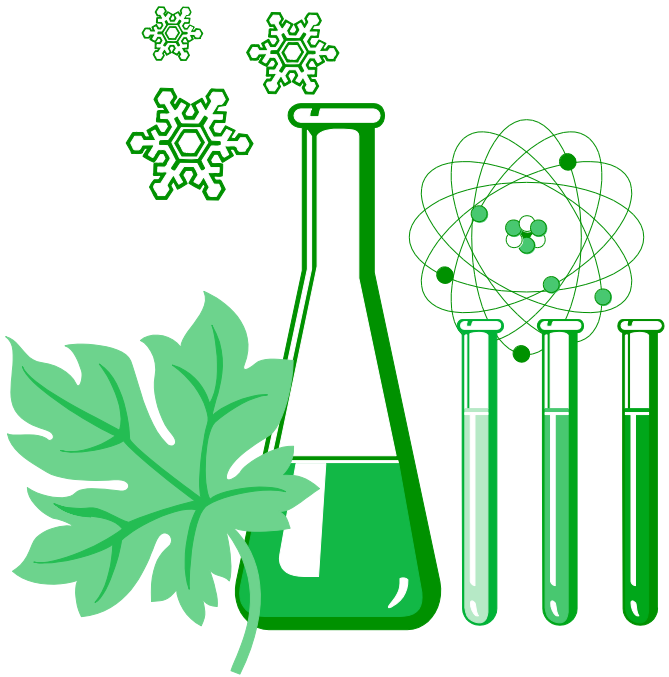
a) identification of rock types;
b) the rock cycle and how transformations between rocks occur;
c) Earth history and fossil evidence;
d) the basic structure of Earth's interior;
e) changes in Earth's crust due to plate tectonics;
f) weathering, erosion, and deposition; and
g) human impact.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
~~The concepts developed in this standard include the following:~~ • Rocks have properties that can be observed, tested, and described. Composition, grain size and textural features, color, and the presence of fossils help with identification. Classification keys (5.1) can aid this process. • Rocks move and change over time due to heat and pressure within ~~the~~ Earth and due to weathering, ~~and~~ erosion, and deposition at the surface. These and other processes constantly change rock from one type to another. • Depending on how rocks are formed, they are classified as sedimentary (layers of sediment cemented together), igneous (melted and cooled, e.g., lava and magma), and metamorphic (changed by heat and pressure). • Scientific evidence indicates ~~the~~ Earth is ~~very~~ ancient — approximately 4.6 billion years old. The age of many rocks can be determined very reliably. Fossils provide information about life and conditions of the past. • Scientific evidence indicates that ~~the~~ Earth is composed of four concentric layers — crust, mantle, ~~inner~~ outer core, and ~~outer~~ inner core — each with its own distinct characteristics. The outer two layers are composed primarily of rocky material. The innermost layers are composed mostly of iron and nickel. Pressure and temperature increase with depth beneath the surface.	In order to meet this standard, it is expected that students ~~should be able to~~ will • apply basic terminology ~~(italic print in overview)~~ to explain how ~~the~~ Earth's surface is constantly changing. • draw and label the rock cycle and describe the major processes and rock types involved. • compare and contrast the origin of igneous, sedimentary, and metamorphic rocks. • identify rock samples (granite, gneiss, slate, limestone, shale, sandstone, and coal), using a rock classification key. • make plausible inferences about changes in ~~the~~ Earth over time based on fossil evidence. This includes the presence of fossils of organisms in sedimentary rocks of Virginia found in the Appalachian~~s~~ Mountains, Piedmont, and Coastal Plain/Tidewater. • describe the structure of Earth in terms of its major layers — crust, mantle, and ~~inner~~ outer and ~~outer~~ inner cores — and how ~~the~~ Earth's interior affects the surface. • differentiate among the three types of plate tectonic boundaries (divergent, convergent, and ~~sliding~~ transform) and how these relate to the changing surface of ~~the~~ Earth and the ocean floor (5.6). • compare and contrast the origin of earthquakes and volcanoes and

5.7 The student will investigate and understand how Earth's surface is constantly changing. Key concepts include

a) identification of rock types;
b) the rock cycle and how transformations between rocks occur;
c) Earth history and fossil evidence;
d) the basic structure of Earth's interior;
e) changes in Earth's crust due to plate tectonics;
f) weathering, erosion, and deposition; and
g) human impact.

~~Overview~~ Understanding the Standard (Background Information for Instructor Use Only)	Essential Knowledge, Skills, and Processes
• ~~The~~ Earth's ~~heat~~ thermal energy causes movement of material within ~~the~~ Earth. Large continent-size blocks (plates) move slowly about ~~the~~ Earth's surface, driven by that ~~heat~~ thermal energy. • Most earthquakes and volcanoes are located at the boundar~~y~~ies of the plates (faults). Plates can move together (convergent boundaries), apart (divergent boundaries), or slip past each other horizontally (~~sliding~~ transform boundaries, also called strike-slip or ~~transform~~ sliding boundaries). • Geological features in the oceans (including trenches and mid-ocean ridges) and on the continents (mountain ranges, including the Appalachian Mountains) are caused by current and past plate movements. • Rocks and other materials on ~~the~~ Earth's surface are constantly being broken down both chemically and physically. The products of weathering include clay, sand, rock fragments, and soluble substances. • ~~Weathered rock m~~Material can be moved by water and wind (eroded) and deposited in new locations as sediment (deposition). • Humans have varying degrees of impact on ~~the~~ Earth's surface through their everyday activities. With careful planning, the impact on the land can be controlled.	how they affect ~~the~~ Earth's surface. • differentiate between weathering, ~~and~~ erosion, and deposition. • design an investigation to locate, chart, and report weathering, ~~and~~ erosion, and deposition at home and on the school grounds. Create a plan to solve erosion and/or deposition problems that may be found. • ~~design an investigation to determine the amount and kinds of weathered rock material found in soil.~~ • describe how people change ~~the~~ Earth's surface and how negative changes can be controlled.



Science Standards of Learning Curriculum Framework

Grade Six

Final Review
November 18, 2010

Commonwealth of Virginia
Board of Education
Richmond, Virginia
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by the

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Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Grade Six
Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of inquiry skills that defines what a student ~~should~~will be able to do when conducting activities and investigations. The various skill categories are described in the "Investigate and Understand" section of the Introduction to the *Science Standards of Learning*, and the skills in science standards 6.1 represent more specifically what a student should be able to do as a result of science experiences in sixth grade. Across the grade levels, the skills in the "Scientific Investigation, Reasoning, and Logic" strand form a nearly continuous sequence of investigative skills. ~~(Please note Appendix, "Science Skills, Scope, & Sequence.")~~ It is important that the classroom teacher understand~~s~~ how the skills in standard 6.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, and 5.1). The sixth-grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed.

6.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) observations are made involving fine discrimination between similar objects and organisms; b) precise and approximate measurements are recorded; c) scale models are used to estimate distance, volume, and quantity; d) hypotheses are stated in ways that identify the independent and dependent variables; e) a method is devised to test the validity of predictions and inferences; f) one variable is manipulated over time, using many repeated trials; g) data are collected, recorded, analyzed, and reported using metric measurements and tools; h) data are analyzed and communicated through graphical representation; i) models and simulations are designed and used to illustrate and explain phenomena and systems; and j) current applications are used to reinforce science concepts.
	~~Understanding the Standard~~ Overview The skills described in standard 6.1 are intended to define the "investigate" component of all of the other sixth-grade standards (6.2–6.9). The intent of standard 6.1 is that students will continue to develop a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed at the sixth grade. Standard 6.1 does not require a discrete unit on scientific investigation because the inquiry skills that make up the standard should be incorporated in all the other sixth-grade standards. It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science, as well as more fully grasp the content-related concepts in the standards. It is also intended that models, simulations and current applications are used throughout the course in order to learn and reinforce science concepts.

6.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) observations are made involving fine discrimination between similar objects and organisms;
b) precise and approximate measurements are recorded;
c) scale models are used to estimate distance, volume, and quantity;
d) hypotheses are stated in ways that identify the independent and dependent variables;
e) a method is devised to test the validity of predictions and inferences;
f) one variable is manipulated over time, using many repeated trials;
g) data are collected, recorded, analyzed, and reported using metric measurements and tools;
h) data are analyzed and communicated through graphical representation;
i) models and simulations are designed and used to illustrate and explain phenomena and systems; and
j) current applications are used to reinforce science concepts.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts a) the natural world is understandable; b) science is based on evidence, both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. • To communicate an observation accurately, one must provide critical details of exactly what is being observed. Using that information, students will be able to differentiate definitively between or among similar objects and/or organisms. • ~~In an effective classification system, accurate comparisons and contrasts are made.~~	In order to meet this standard, it is expected that students ~~should be able to~~ will • make connections between the components of the nature of science and their investigations and the greater body of scientific knowledge and research. • make observations that can be used to discriminate similar objects and organisms, paying attention to fine detail. • ~~develop a classification key that uses numerous characteristics.~~ • make precise and consistent measurements and estimations. • create approximate scale models to demonstrate an understanding of distance, volume, and quantity. • differentiate between independent ~~(manipulated)~~ and dependent ~~(responding)~~ variables in a hypothesis. • propose hypotheses or predictions from observed patterns. • compare and contrast predictions and inferences. Analyze and judge the evidence, observations, scientific principles, and data used in making predictions and inferences. • design an experiment in which one variable is manipulated over many

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h) data are analyzed and communicated through graphical representation;
i) models and simulations are designed and used to illustrate and explain phenomena and systems; and
j) current applications are used to reinforce science concepts.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
• Systematic investigations require accurate measurements; however, in the absence of precision tools, observers must record careful estimations. • Scale models must maintain relative values of size and/or quantity in order to maintain the integrity of the object or topic being modeled. • An experiment is a structured test of a hypothesis. A hypothesis is stated in terms of a testable relationship. • A scientific prediction is a forecast about what may happen in some future situation. It is based on the application of scientific principle and factual information. • ~~An inference is a conclusion based on evidence about events that have already occurred.~~ An inference is an explanation based on observations and background knowledge. A conclusion is formulated from collected data. For example, one might observe darkly colored pond water and make the inference that it is polluted. However, only after data are collected can a conclusion be formulated. • Patterns discerned from direct observations can be the basis for predictions or hypotheses that attempt to explain the mechanism responsible for the pattern. • Accurate observations and evidence are necessary to draw realistic and plausible conclusions.	trials. • collect, record, analyze, and report data, using metric terminology and tools. • ~~Organize~~ analyze and communicate data, using graphs (bar, line, and circle), charts, and diagrams. • design a model that explains a sequence, for example, ~~the sequence of events involved in the process of photosynthesis.~~ the sequence of events involved in the formation of a cloud.

6.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) observations are made involving fine discrimination between similar objects and organisms;
b) precise and approximate measurements are recorded;
c) scale models are used to estimate distance, volume, and quantity;
d) hypotheses are stated in ways that identify the independent and dependent variables;
e) a method is devised to test the validity of predictions and inferences;
f) one variable is manipulated over time, using many repeated trials;
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h) data are analyzed and communicated through graphical representation;
i) models and simulations are designed and used to illustrate and explain phenomena and systems; and
j) current applications are used to reinforce science concepts.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
• In order to conduct an experiment, one must recognize all of the potential variables that can affect an outcome. • In a scientific investigation, data should be collected, recorded, analyzed, and reported using appropriate metric measurement and tools. • In a scientific investigation, data should be organized and communicated through appropriate graphical representation (graph, chart, table, and diagram). • Models provide a way of visually representing abstract concepts. The use of models permits students to order events or processes. • Science concepts are applied through observations and connections with everyday life and technology.	

Grade Six
Science Strand

Force, Motion, and Energy

The strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism; types of motion; simple machines; and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

6.2	The student will investigate and understand basic sources of energy, their origins, transformations, and uses. Key concepts include a) potential and kinetic energy; b) the role of the sun in the formation of most energy sources on Earth; c) nonrenewable energy sources; d) renewable energy sources; and e) energy transformations.
	~~Understanding the Standard~~ Overview ~~Most~~ Many sources of energy on ~~the~~ Earth are the result of solar radiation~~,~~. ~~either~~ This can be energy the Earth is currently receiving or energy that has been stored as fossil fuels. ~~Heat energy also comes from the Earth's interior.~~ All energy exists in two basic forms, — kinetic and potential. Understanding the forms of energy and their transformations will provide the foundation for students to investigate the transfer of energy within living and Earth systems as well as to understand chemical reactions, force, and motion. This standard builds upon concepts of energy sources introduced in science standard 3.11. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and an understanding of the nature of science (6.1) in the context of the key concepts presented in this standard.

6.2 The student will investigate and understand basic sources of energy, their origins, transformations, and uses. Key concepts include
a) potential and kinetic energy;
b) the role of the sun in the formation of most energy sources on Earth;
c) nonrenewable energy sources;
d) renewable energy sources; and
e) energy transformations.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • Potential energy is energy that is not "in use" and available to do work. Kinetic energy is energy that is "in use" — the energy a moving object has due to its motion. For example, moving water and wind have kinetic energy. The chemical energy in fossil fuels is potential energy until it is released. • ~~Some important sources of energy include fossil fuels, wood, wind, water (hydropower), the sun (solar energy), and the Earth's interior.~~ • Solar energy from the ancient past is stored in fossil fuels, such as coal ~~and~~, petroleum, and natural gas. Fossil fuels are rich in the elements carbon and hydrogen. These sources of energy take very long periods of time to form and once depleted, are essentially nonrenewable. Nuclear power is also a source of nonrenewable energy. • Many of ~~the~~ Earth's energy resources are available on a perpetual basis. These include solar, wind, water (hydropower, tidal and waves), biofuels and geothermal energy. Some energy sources can be replenished over relatively short periods of time. These include wood and other biomass. All are considered renewable. • Secondary sources of energy, such as electricity, are used to store, move, and deliver energy easily in usable form. Hydrogen is also a secondary source of energy, also called an energy carrier. • ~~Heat and light~~ Thermal and radiant energy can be converted into mechanical energy, chemical energy, and electrical energy and back again.	In order to meet this standard, it is expected that students ~~should be able~~ will • compare and contrast potential and kinetic energy through common examples found in the natural environment. • analyze and describe the transformations of energy involved with the formation and burning of coal and other fossil fuels. • compare and contrast renewable (solar, wind, water [hydropower, tidal and waves], biofuels, geothermal, and biomass) and nonrenewable energy sources (coal, petroleum, natural gas, nuclear power). • explain that hydrogen is not an energy source, but a means of storing and transporting energy. • design an application of the use of solar and wind energy. • chart and analyze the energy a person uses during a 24-hour period and determine the sources. • compare and contrast energy sources in terms of their origins, how they are utilized, and their availability. • analyze the advantages and disadvantages of using various energy sources and their impact on climate and the environment. • analyze and describe how the United States' energy use has changed over time. • analyze and describe sources of energy used in Virginia related to energy use nationally and globally.

6.2	The student will investigate and understand basic sources of energy, their origins, transformations, and uses. Key concepts include a) potential and kinetic energy; b) the role of the sun in the formation of most energy sources on Earth; c) nonrenewable energy sources; d) renewable energy sources; and e) energy transformations.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
	• predict the impact of unanticipated energy shortages. • comprehend and apply basic terminology related to energy sources and transformations. • create and interpret a model or diagram of an energy transformation. • design an investigation that demonstrates how light energy (radiant energy) can be ~~being~~ transformed into other forms of energy (mechanical, chemical and electrical).

6.3	The student will investigate and understand the role of solar energy in driving most natural processes within the atmosphere, the hydrosphere, and on Earth's surface. Key concepts include a) Earth's energy budget; b) the role of radiation and convection in the distribution of energy; c) the motion of the atmosphere and the oceans; d) cloud formation; and e) the role of thermal energy in weather-related phenomena including thunderstorms and hurricanes.
	~~Understanding the Standard~~ Overview The key concepts defined in this standard are intended to expand student understanding of the effects of solar radiation entering ~~the~~ Earth's atmosphere on weather and ocean current patterns. The distribution of energy through convection and radiation are explored as students study cloud formation and movement patterns of the atmosphere and the world's oceans. This standard is closely related to standards 6.2 and 6.6 and builds on the weather concepts developed in standard 4.6 and concepts of visible light in standard 5.3. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and an understanding of the nature of science (6.1) in the context of the key concepts presented in this standard.

6.3 The student will investigate and understand the role of solar energy in driving most natural processes within the atmosphere, the hydrosphere, and on Earth's surface. Key concepts include

a) Earth's energy budget;
b) the role of radiation and convection in the distribution of energy;
c) the motion of the atmosphere and the oceans;
d) cloud formation; and
e) the role of thermal energy in weather-related phenomena including thunderstorms and hurricanes.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • ~~The~~ Earth receives only a very small portion of the sun's energy, yet this energy is responsible for powering the motion of the atmosphere, the oceans, and many processes at ~~the~~ Earth's surface. • Solar radiation is made up of different types of radiation (including infrared, visible light, and ultraviolet). • Incoming solar radiation is in close balance with the energy that leaves the atmosphere; otherwise t~~he~~ Earth would heat up or cool down. Excess carbon dioxide and other gases may disrupt this balance, creating a ~~Greenhouse Effect~~ greenhouse effect. • About one-third of the sun's incoming energy is reflected back out to space. About one-half of the energy striking the Earth is absorbed by ~~the~~ Earth's surface. • ~~The~~ Earth's surface is heated unequally. • When air or water is heated, the molecules move faster and farther apart, reducing their density and causing them to rise. Cooler air or water molecules move more slowly and are denser than warm air or water. Warm air or water rising coupled with cooler air or water descending forms a cyclic rising/falling pattern called *convection*. • Radiation and convection from ~~the~~ Earth's surface transfer ~~heat~~ thermal energy. This energy powers the global circulation of the atmosphere and the oceans on our planet. • As bodies of water (oceans, lakes, rivers, etc.) absorb ~~heat~~ thermal energy, the water evaporates ~~forming clouds~~ causing the air to be warm	In order to meet this standard, it is expected that students ~~should be able to~~ will • comprehend and apply basic terminology related to solar energy, including wavelength; ultraviolet, visible, and infrared radiation; and reflection and absorption. • analyze and interpret a chart or diagram showing ~~the~~ Earth's energy budget. • analyze, model, and explain the ~~G~~greenhouse ~~E~~effect in terms of the energy entering and leaving the atmosphere. • design an investigation to determine the effect of sunlight on the heating of a surface. • analyze and explain how convection currents occur and how they distribute ~~heat~~ thermal energy in the atmosphere and oceans. • analyze the role of heating and cooling in the formation of clouds. • order the sequence of events that takes place in the formation of a cloud. • describe the relationship between thermal energy and the formation of hurricanes and thunderstorms.

6.3	The student will investigate and understand the role of solar energy in driving most natural processes within the atmosphere, the hydrosphere, and on Earth's surface. Key concepts include a) Earth's energy budget; b) the role of radiation and convection in the distribution of energy; c) the motion of the atmosphere and the oceans; d) cloud formation; and e) the role of thermal energy in weather-related phenomena including thunderstorms and hurricanes.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
and moist. Warm, moist air is less dense than cold, dry air, so it rises relative to colder, drier air. As warm, moist air rises, it ~~actually~~ gives off some ~~heat~~ thermal energy as the moisture condenses, forming clouds. Clouds are not gaseous water vapor; rather they are minute, condensed water particles. • Some thunderstorms are formed where the land is strongly heated. Hurricanes form over warm, tropical water and are fed by the energy of that water.	

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, states of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure of classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

6.4	The student will investigate and understand that all matter is made up of atoms. Key concepts include a) atoms consist of particles, including electrons, protons, and neutrons; b) atoms of a particular element are alike but are different 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 limited number of elements comprise the largest portion of the solid Earth, living matter, the oceans, and the atmosphere.
	~~Understanding the Standard~~ Overview Standard 6.4 focuses on an understanding of the basic structure of the atom, including electrons, protons, and neutrons. The concepts defined in standard 6.4 build on students' basic understanding of the ~~structure~~ concept of matter as introduced in science standards 3.3 and 5.4. Knowledge of basic chemistry concepts is fundamental to understanding the physical sciences, life processes, and Earth and environmental science ideas. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (6.1) in the context of the key concepts presented in this standard.

6.4 The student will investigate and understand that all matter is made up of atoms. Key concepts include
a) atoms consist of particles, including electrons, protons, and neutrons;
b) atoms of a particular element are alike but are different 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 limited number of elements comprise the largest portion of the solid Earth, living matter, the oceans, and the atmosphere.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • The basic structural components of ~~the~~ a typical atom are electrons, protons, and neutrons. Protons and neutrons comprise the nucleus of an atom. • An element is a form of matter made up of one type of atom. The atoms of an element are basically alike, though the number of neutrons may vary. • The atoms of one element differ from those of another element in the number of protons. • Elements can be represented by chemical symbols. • Two or more atoms of different elements may combine to form a compound. • Compounds can be represented by chemical formulas. Each different element in the compound is represented by its unique symbol. The number of each type of element in the compound (other than 1) is represented by a small number (the subscript) to the right of the element symbol. • Chemical equations can be used to model chemical changes, illustrating how elements become rearranged in a chemical reaction. • A limited number of elements, including silicon, aluminum, iron, sodium, calcium, potassium, magnesium, hydrogen, oxygen, nitrogen, and carbon, form the largest portion of the Earth's crust, living matter, the oceans, and the atmosphere.	In order to meet this standard, it is expected that students ~~should be able to~~ will • create and interpret a simplified modern model of the structure of an atom. • compare and contrast the atomic structure of two different elements. • explain that elements are represented by symbols. • identify the name and number of each element present in a simple molecule or compound, such as O_2, H_2O, CO_2, or $CaCO_3$. • model a simple chemical change with an equation and account for all atoms. Distinguish the types of elements and number of each element in the chemical equation. (Balancing equations will be further developed in Physical Science.~~)~~. • name some of the predominant elements found in the atmosphere, the oceans, living matter, and ~~the~~ Earth's crust.

6.5	The student will investigate and understand the unique properties and characteristics of water and its roles in the natural and human-made environment. Key concepts include a) water as the universal solvent; b) the properties of water in all three phases; c) the action of water in physical and chemical weathering; d) the ability of large bodies of water to store thermal energy and moderate climate; e) the importance of water for agriculture, power generation, and public health; and f) the importance of protecting and maintaining water resources.

~~Understanding the Standard~~ Overview

Standard 6.5 is intended to develop student understanding of the unique properties of water and the importance of protecting and managing water resources. Understanding the structure, properties, and behavior of the water molecule is fundamental to understanding more complex environmental systems. Concepts like solubility, surface tension, cohesion, adhesion, density, condensation, and evaporation can be investigated to appreciate why the properties of water are critical to life processes and living things. This standard also introduces the concept of the ability of large bodies of water to moderate the climate on land. The connections between water resources and agriculture, power generation, and public health are also investigated. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and an understanding of the nature of science (6.1) in the context of the key concepts presented in this standard.

6.5 The student will investigate and understand the unique properties and characteristics of water and its roles in the natural and human-made environment. Key concepts include

a) water as the universal solvent;
b) the properties of water in all three phases;
c) the action of water in physical and chemical weathering;
d) the ability of large bodies of water to store thermal energy and moderate climate;
e) the importance of water for agriculture, power generation, and public health; and
f) the importance of protecting and maintaining water resources.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • Among water's unique properties is that one side of each water molecule is slightly negative and the other is slightly positive. Individual water molecules, therefore, attract other water molecules like little magnets as the slightly positive portion of a water molecule is attracted to the slightly negative portion of an adjacent water molecule. In this way, water molecules "stick together." • Due to water's polar nature, ~~A~~ a large number of substances will "dissolve" in water. For this reason, water is often called the universal solvent. • Water is the only compound that commonly exists in all three states (solid, liquid, gas) on Earth. The unique properties of water are a major factor in the ability of our planet to sustain life. • Additional properties of water are its high surface tension and the large range of temperature (0–100 degrees Celsius) in which it can be found in the liquid state, as well as the fact that, unlike other substances, ~~it expands when it freezes. Ice~~ solid water is less dense than liquid water. • Water is able to absorb ~~heat~~ thermal energy without showing relatively large changes in temperature. Large bodies of water act to moderate the climate of surrounding areas by absorbing ~~heat~~ thermal energy in summer and slowly releasing that ~~heat~~ energy in the winter. For this reason, the climate near large bodies of water is slightly milder than areas without large bodies of water. • Water (rain, ice, snow) has shaped our environment by physically and	In order to meet this standard, it is expected that students ~~should be able to~~ will • comprehend and apply key terminology related to water and its properties and uses. • model and explain the shape and composition of a water molecule. • design an investigation to demonstrate the ability of water to dissolve materials. • ~~design an investigation to determine the relative density of liquid and solid water at various temperatures.~~ • ~~compare the relative densities of liquid and solid water.~~ • comprehend the adhesive and cohesive properties of water. • ~~design an investigation to determine~~ compare the effects of ~~heat on~~ adding thermal energy to the states of water. • ~~model and~~ explain why ice is less dense than liquid water. • relate the three states of water to the water cycle. • design an investigation to model the action of freezing water on rock material. • design an investigation to determine the presence of water in plant material (e.g., a fruit). • infer how the unique properties of water are key to the life processes

6.5 The student will investigate and understand the unique properties and characteristics of water and its roles in the natural and human-made environment. Key concepts include

a) water as the universal solvent;
b) the properties of water in all three phases;
c) the action of water in physical and chemical weathering;
d) the ability of large bodies of water to store thermal energy and moderate climate;
e) the importance of water for agriculture, power generation, and public health; and
f) the importance of protecting and maintaining water resources.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
chemically weathering rock and soil and transporting sediments. Freezing water can break rock without any change in the minerals that form the rock (physical weathering). This usually produces small particles and sand. Water with dissolved gases and other chemicals causes the minerals in rocks to be changed, leading to the deterioration of the rock (chemical weathering). • ~~Scientific evidence indicates that the Earth formed about four-and-a-half billion years ago from the dust and debris orbiting the sun. Due to gravity, this debris became compacted and grew quite hot, creating hot gases, including water vapor and carbon dioxide. Over millions of years, the Earth and its gases cooled, and seas are believed to have formed when the Earth cooled enough for water vapor in the atmosphere to condense.~~ • Most of Earth's water is salt water in the oceans (97 percent). ~~Available n~~Nonfrozen, fresh water makes up less than 1 percent of the water on Earth. • ~~Water occurs on Earth in oceans, lakes, rivers, streams, and in rock layers underground called aquifers. A large amount of water is also found in the bodies of living things.~~ • ~~The first human settlements were established near springs, rivers, and lakes. Reliable fresh water sources and irrigation systems allowed civilizations to grow and flourish. As cities grew, different strategies (tunnels, aqueducts, wells, cisterns, pumps, reservoirs) were employed to collect water.~~ • Water is essential for agriculture. Crops watered by reliable irrigation systems are more productive~~,~~ and harvests more dependable.	of organisms. • design an investigation to model the action of acidified water on building materials such as concrete, limestone, or marble. • chart, record, and describe evidence of chemical weathering in the local environment. • analyze and explain the difference in average winter temperatures among areas in central and western Virginia and cities and counties along the Chesapeake Bay and Atlantic coast. • explain the role of water in power generation. • describe the importance of careful management of water resources.

6.5	The student will investigate and understand the unique properties and characteristics of water and its roles in the natural and human-made environment. Key concepts include a) water as the universal solvent; b) the properties of water in all three phases; c) the action of water in physical and chemical weathering; d) the ability of large bodies of water to store thermal energy and moderate climate; e) the importance of water for agriculture, power generation, and public health; and f) the importance of protecting and maintaining water resources.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
• Water is an important resource used in power generation. Hydroelectric power plants make use of the kinetic energy of water as it flows through turbines. Water is also heated in power plants and turned to steam. The steam is used to turn turbines, which generate electricity. • In the past, streams and rivers were often used to dispose of human waste, and open sewers were common. During the mid-1800s, public health officials recognized the connection between disease outbreaks and contamination of public wells and drinking water. Advances in water treatment and sanitary sewers have helped eliminate diseases associated with human waste. • Due to water's importance in power generation, agriculture, and human health, it is important to conserve water resources.	

6.6	The student will investigate and understand the properties of air and the structure and dynamics of Earth's atmosphere. Key concepts include a) air as a mixture of gaseous elements and compounds; b) pressure, temperature, and humidity; c) atmospheric changes with altitude; d) natural and human-caused changes to the atmosphere and the importance of protecting and maintaining air quality; e) the relationship of atmospheric measures and weather conditions; and f) basic information from weather maps, including fronts, systems, and basic measurements.
	Understanding the Standard Standard 6.6 is intended to provide students with a basic understanding of the properties of air, the structure of the atmosphere, weather, and air quality. Students need to understand there are both natural and human-caused changes to the atmosphere and that the results of these changes are not yet fully known. A basic understanding of weather and weather prediction builds on the key concepts in standard 4.6. Standard 6.6 also focuses on student understanding of air quality as an important parameter of human and environmental health. It is important to make the obvious connections between this standard and the other sixth-grade standards. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and an understanding of the nature of science (6.1) in the context of the key concepts presented in this standard.

6.6 The student will investigate and understand the properties of air and the structure and dynamics of Earth's atmosphere. Key concepts include

a) air as a mixture of gaseous elements and compounds;
b) pressure, temperature, and humidity;
c) atmospheric changes with altitude;
d) natural and human-caused changes to the atmosphere and the importance of protecting and maintaining air quality;
e) the relationship of atmospheric measures and weather conditions; and
f) basic information from weather maps, including fronts, systems, and basic measurements.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • Air is a mixture of gaseous elements and compounds. These include nitrogen, oxygen, water, argon and carbon dioxide. Nitrogen makes up the largest proportion of air. • Air exerts pressure. Air pressure decreases as altitude increases. • Moisture in the air is called humidity. • The atmosphere is made up of layers (troposphere, stratosphere, mesosphere, and thermosphere) that have distinct characteristics. • Temperature decreases as altitude increases in the lowest layer of the atmosphere. • Most of the air that makes up the atmosphere is found in the troposphere (the lowest layer). Virtually all weather takes place there. • Forest fires and volcanic eruptions are two natural processes that affect ~~the~~ Earth's atmosphere. Many gaseous compounds and particles are released into the atmosphere by human activity. All of the effects of these materials are not yet fully understood. • The amounts of ~~heat~~ thermal energy and water vapor in the air and the pressure of the air largely determine what the weather conditions are. • Clouds are important indicators of atmospheric conditions. Clouds are found at various levels within the troposphere. Three major types of clouds are cumulus, stratus, and cirrus. • Ozone, a form of oxygen, can form near the surface when exhaust	In order to meet this standard, it is expected that students ~~should be able to~~ will • comprehend and apply basic terminology related to air and the atmosphere. • identify the composition and physical characteristics of the atmosphere. • analyze and interpret charts and graphs of the atmosphere in terms of temperature and pressure. • measure and record air temperature, air pressure, and humidity, using appropriate units of measurement and tools. • analyze and explain some of the effects that natural events and human activities may have on weather, atmosphere, and climate. • evaluate their own roles in protecting air quality. • design an investigation to relate temperature, barometric pressure, and humidity to changing weather conditions. • compare and contrast cloud types and relate cloud types to weather conditions. • compare and contrast types of precipitation. • compare and contrast weather-related phenomena, including thunderstorms, tornadoes, hurricanes, and drought. • interpret basic weather maps and make forecasts based on the information presented.

6.6	The student will investigate and understand the properties of air and the structure and dynamics of Earth's atmosphere. Key concepts include a) air as a mixture of gaseous elements and compounds; b) pressure, temperature, and humidity; c) atmospheric changes with altitude; d) natural and human-caused changes to the atmosphere and the importance of protecting and maintaining air quality; e) the relationship of atmospheric measures and weather conditions; and f) basic information from weather maps, including fronts, systems, and basic measurements.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
pollutants react with sunlight. This pollutant can cause health problems. Naturally occurring ozone is also found in the upper atmosphere and helps to shield ~~the~~ Earth from ultraviolet radiation. • Maintaining good air quality is a crucial goal for modern society, and it is everyone's responsibility to work toward it. • Weather maps show much useful information about descriptive air measurements, observations, and boundaries between air masses (fronts). The curved lines showing areas of equal air pressure and temperature are key features of weather maps. Weather maps are important for understanding and predicting the weather.	• map the movement of cold and warm fronts and interpret their effects on observable weather conditions.

Grade Six
Science Strand

Living Systems

The strand begins in second grade and builds from basic to more complex understandings of a system, both at the ecosystem level and at the level of the cell. The concept of kingdoms of organisms and a general classification of organisms are also presented. The other major topics developed in the strand include the types of relationships among organisms in a food chain, different types of environments and the organisms they support, and the relationship between organisms and their nonliving environment. This strand includes science standards 2.5, 3.5, 3.6, 4.5, 5.5, and 6.7.

6.7	The student will investigate and understand the natural processes and human interactions that affect watershed systems. Key concepts include a) the health of ecosystems and the abiotic factors of a watershed; b) the location and structure of Virginia's regional watershed systems; c) divides, tributaries, river systems, and river and stream processes; d) wetlands; e) estuaries; f) major conservation, health, and safety issues associated with watersheds; and g) water monitoring and analysis using field equipment including hand-held technology.
	~~Understanding the Standard~~ Overview Standard 6.7 is intended to provide students with a basic understanding of how natural processes and human interactions impact watershed systems. This includes an understanding of the physical geography of Virginia's portions of the three major watershed systems (the Chesapeake Bay, the North Carolina sounds, and the Gulf of Mexico) and the various features associated with moving water (surface and groundwater). Wetlands have become an important focus of scientists as we learn their role in flood and erosion control as well as their importance as habitat for many species of living things. Students are introduced to major safety and conservation issues associated with watersheds and become familiar with the testing parameters and tools used in the field. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and an understanding of the nature of science (6.1) in the context of the key concepts presented in this standard.

6.7 The student will investigate and understand the natural processes and human interactions that affect watershed systems. Key concepts include

a) the health of ecosystems and the abiotic factors of a watershed;
b) the location and structure of Virginia's regional watershed systems;
c) divides, tributaries, river systems, and river and stream processes;
d) wetlands;
e) estuaries;
f) major conservation, health, and safety issues associated with watersheds; and
g) water monitoring and analysis using field equipment including hand-held technology.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • An ecosystem is made up of the biotic (living) community and the abiotic (nonliving) factors that affect it. The health of an ecosystem is directly related to water quality. • Abiotic factors determine ecosystem type and its distribution of plants and animals as well as the usage of land by people. Abiotic factors include water supply, topography, landforms, geology, soils, sunlight, and air quality/O_2 availability. • Human activities can alter abiotic components and thus accelerate or decelerate natural processes. For example, people can affect the rate of natural erosion. Plowing cropland can cause greater erosion, while planting trees can prevent it. Flood protection/wetland loss is another example. • A watershed is the land that water flows across or through on its way to a stream, lake, wetland, or other body of water. Areas of higher elevations, such as ridgelines and divides, separate watersheds. • The three major regional watershed~~s~~ systems in Virginia lead to the Chesapeake Bay, the North Carolina sounds, or the Gulf of Mexico. • River systems are made up of tributaries of smaller streams that join along their courses. Rivers and streams generally have wide, flat, border areas, called flood plains, onto which water spills out at times of high flow. • Rivers and streams carry and deposit sediment. As water flow decreases	In order to meet this standard, it is expected that students ~~should be able to~~ will • comprehend and apply basic terminology related to watersheds. • use topographic maps to determine the location and size of Virginia's regional watershed systems. • locate their own local watershed and the rivers and streams associated with it. • design an investigation to model the effects of stream flow on various slopes. • analyze and explain the functioning of wetlands and appraise the value of wetlands to humans. • ~~describe an example of a wetland.~~ • explain what an estuary is and why it is important to people. • propose ways to maintain water quality within a watershed. • explain the factors that affect water quality in a watershed and how those factors can affect an ecosystem. • forecast potential water-related issues that may become important in the future. • locate and critique a media article or editorial (print or electronic) concerning water use or water quality. Analyze and evaluate the

6.7 The student will investigate and understand the natural processes and human interactions that affect watershed systems. Key concepts include

a) the health of ecosystems and the abiotic factors of a watershed;
b) the location and structure of Virginia's regional watershed systems;
c) divides, tributaries, river systems, and river and stream processes;
d) wetlands;
e) estuaries;
f) major conservation, health, and safety issues associated with watersheds; and
g) water monitoring and analysis using field equipment including hand-held technology.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
in speed, the size of the sediment it carries decreases. • Wetlands form the transition zone between dry land and bodies of water such as rivers, lakes, or bays. Both tidal and nontidal wetlands perform important water quality functions, including regulating runoff by storing flood waters; reducing erosion by slowing down run-off; maintaining water quality by filtering sediments, trapping nutrients, and breaking down pollutants; and recharging groundwater. They also provide food and shelter for wildlife and fish and nesting and resting areas for migratory birds. • Estuaries perform important functions, such as providing habitat for many organisms and serving as nurseries for their young. • The Chesapeake Bay is an estuary where fresh and salt water meet and are mixed by tides. It is the largest estuary in the contiguous United States and one of the most productive. • Water quality monitoring is the collection of water samples to analyze chemical and/or biological parameters. Simple parameters include pH, temperature, salinity, dissolved oxygen, turbidity, and the presence of macroinvertebrate organisms.	science concepts involved. • argue for and against commercially developing a parcel of land containing a large wetland area. Design and defend a land-use model that minimizes negative impact. • measure, record, and analyze a variety of water quality indicators and describe what they mean to the health of an ecosystem.

Grade Six
Science Strand

Interrelationships in Earth/Space Systems

The strand focuses on student understanding of how Earth systems are connected and how ~~the~~ Earth interacts with other members of the solar system. The topics developed include shadows; relationships between the sun and ~~the~~ Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards K.7, 1.6, 2.6, 3.7, 4.6, 4.7, 4.8, 5.6, and 6.8.

6.8	The student will investigate and understand the organization of the solar system and the interactions among the various bodies that comprise it. Key concepts include a) the sun, moon, Earth, other planets and their moons, dwarf planets, meteors, asteroids, and comets; b) relative size of and distance between planets; c) the role of gravity; d) revolution and rotation; e) the mechanics of day and night and the phases of the moon; f) the unique properties of Earth as a planet; g) the relationship of Earth's tilt and the seasons; h) the cause of tides; and i) the history and technology of space exploration.
	~~Understanding the Standard~~ Overview Standard 6.8 is intended to provide students with a basic understanding of the solar system~~, how it is organized,~~ and the relationships among bodies within the solar system. This standard develops an understanding of ~~the~~ Earth as part of the solar system and builds significantly on standards 3.8 ~~and,~~ 4.7, and 4.8. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and an understanding of the nature of science (6.1) in the context of the key concepts presented in this standard.

6.8 The student will investigate and understand the organization of the solar system and the interactions among the various bodies that comprise it. Key concepts include

a) the sun, moon, Earth, other planets and their moons, dwarf planets, meteors, asteroids, and comets;
b) relative size of and distance between planets;
c) the role of gravity;
d) revolution and rotation;
e) the mechanics of day and night and the phases of the moon;
f) the unique properties of Earth as a planet;
g) the relationship of Earth's tilt and the seasons;
h) the cause of tides; and
i) the history and technology of space exploration.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • The solar system consists of the sun, moon, Earth, other planets and their moons, meteors, asteroids, and comets. Each body has its own characteristics and features. • The distance between planets and sizes of the planets var~~ies~~y greatly. The outer, "gas" planets are very large, and the four inner planets are comparatively small and rocky. • Gravity is a force that keeps the planets in motion around the sun. Gravity acts everywhere in the universe. • Planets revolve around the sun, and moons revolve around planets. A planet rotates upon an axis. • A dwarf planet revolves around the sun, and can maintain a nearly round shape as planets do, but it cannot move other objects away from its orbital neighborhood. • As ~~the~~ Earth rotates, different sides of ~~the~~ Earth face toward or away from the sun, thus causing day and night, respectively. • The phases of the moon are caused by its position relative to ~~the~~ Earth and sun. • ~~The~~ Earth is a rocky planet, extensively covered with large oceans of liquid water and having frozen ice caps in its polar regions. ~~The~~ Earth	In order to meet this standard, it is expected that students ~~should be able to~~ will • describe the ~~nine~~ planets and their relative positions from the sun. • compare the characteristics of Pluto to the planets and explain its designation as a dwarf planet. • design and interpret a scale model of the solar system. (A scale model may be a physical representation of an object or concept. It can also be a mathematical representation that uses factors such as ratios, proportions, and percentages.) • explain the role of gravity in the solar system. • compare and contrast revolution and rotation and apply these terms to the relative movements of planets and ~~moons~~ their moons. • model and describe how day and night and the phases of the moon occur. • model and describe how ~~the~~ Earth's axial tilt and its annual orbit around the sun cause the seasons. • describe the unique characteristics of planet Earth. • discuss the relationship between the gravitational pull of the moon and the cycle of tides.

6.8	The student will investigate and understand the organization of the solar system and the interactions among the various bodies that comprise it. Key concepts include a) the sun, moon, Earth, other planets and their moons, dwarf planets, meteors, asteroids, and comets; b) relative size of and distance between planets; c) the role of gravity; d) revolution and rotation; e) the mechanics of day and night and the phases of the moon; f) the unique properties of Earth as a planet; g) the relationship of Earth's tilt and the seasons; h) the cause of tides; and i) the history and technology of space exploration.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
has a protective atmosphere consisting predominantly of nitrogen and oxygen and has a magnetic field. The atmosphere and the magnetic field help shield ~~the~~ Earth's surface from harmful solar radiation. Scientific evidence indicates that ~~the~~ Earth is about 4.5 billion years old. • Seasons are caused by a combination of the tilt of ~~the~~ Earth on its axis, the curvature of Earth's surface and, thus, the angle at which sunlight strikes the surface of ~~the~~ Earth during its annual revolution around the sun. • Tides are the result of the gravitational pull of the moon and sun on the surface waters of ~~the~~ Earth. • The ideas of Ptolemy, Aristotle, Copernicus, and Galileo contributed to the development of our understanding of the solar system. • With the development of new technology over the last half-century, our knowledge of the solar system has increased substantially.	• compare and contrast the ideas of Ptolemy, Aristotle, Copernicus, and Galileo related to the solar system. • create and interpret a timeline highlighting the advancements in solar system exploration over the past half century. This should include information on the first modern rockets, artificial satellites, orbital missions, missions to the moon, Mars robotic explorers, and exploration of the outer planets.

Earth Resources

The strand focuses on student understanding of the role of resources in the natural world and how people can utilize those resources in a sustainable way. An important idea represented in this strand is the ~~concept of management of resource use~~ importance of managing resources. This begins with basic ideas of conservation and proceeds to more abstract consideration of costs and benefits. The topics developed include conservation of materials, soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards ~~K.10~~ K.11, 1.8, 2.8, 3.10, 3.11, ~~4.8~~ 4.9, and 6.9.

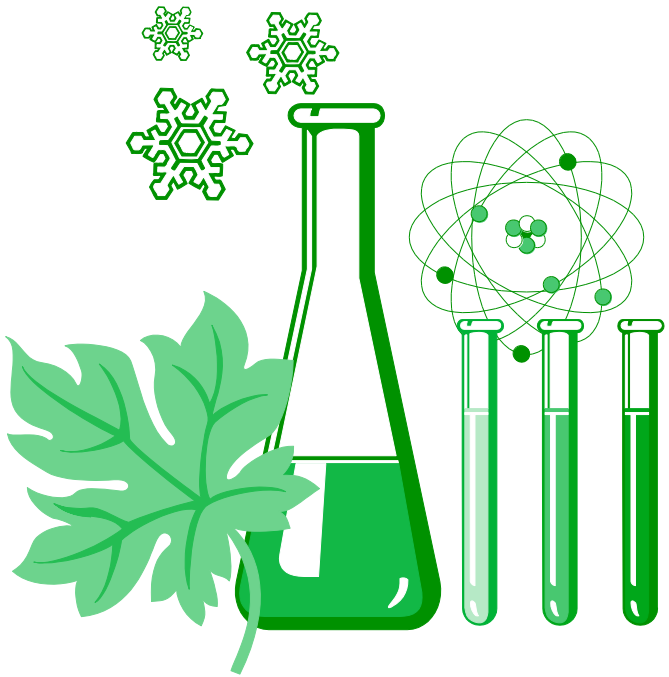
6.9	The student will investigate and understand public policy decisions relating to the environment. Key concepts include a) management of renewable resources; b) management of nonrenewable resources; c) the mitigation of land-use and environmental hazards through preventive measures; and d) cost/benefit tradeoffs in conservation policies.
	~~Understanding the Standard~~ Overview Standard 6.9 is intended to develop student understanding of the importance of ~~the~~ Earth's natural resources, the need to manage them, how they are managed, and the analysis of costs and benefits in making decisions about those resources. It applies and builds on the concepts described in several lower grades, especially science standard 4.~~8~~9. Knowledge gained from this standard will be important to understanding numerous concepts in Life Science and Earth Science. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (6.1) in the context of the key concepts presented in this standard.

6.9 The student will investigate and understand public policy decisions relating to the environment. Key concepts include
a) management of renewable resources;
b) management of nonrenewable resources;
c) the mitigation of land-use and environmental hazards through preventive measures; and
d) cost/benefit tradeoffs in conservation policies.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • People, as well as other living organisms, are dependent upon the availability of clean water and air and a healthy environment. • Local, state, and federal governments have significant roles in managing and protecting air, water, plant, and wildlife resources. • ~~Modern society is dependent upon many finite resources, including coal, oil, natural gas, and nuclear power.~~ • Modern industrial society is dependent upon energy. Fossil fuels are the major sources of energy in developed and industrialized nations and should be managed to minimize adverse impacts. • Many renewable and nonrenewable resources are managed by the private sector (private individuals and corporations). • Renewable resources should be managed so that they produce continuously. Sustainable development makes decisions about long-term use of the land and natural resources for maximum community benefit for the longest time and with the least environmental damage. • Regulations, incentives, and voluntary efforts help conserve resources and protect environmental quality. • Conservation of resources and environmental protection begin with ~~the~~ individual acts of stewardship. • Use of renewable (water, air, soil, plant life, animal life) and nonrenewable resources (coal, oil, natural gas, nuclear power, and mineral resources) must be considered in terms of their cost/benefit tradeoffs.	In order to meet this standard, it is expected that students ~~should be able to~~ will • differentiate between renewable and nonrenewable resources. • describe the role of local and state conservation professionals in managing natural resources. These include wildlife protection; forestry and waste management; and air, water, and soil conservation. • analyze resource-use options in everyday activities and determine how personal choices have costs and benefits related to the generation of waste. • analyze how renewable and nonrenewable resources are used and managed within the home, school, and community. • analyze reports, media articles, and other narrative materials related to waste management and resource use to determine various perspectives concerning the costs/benefits in real-life situations. • evaluate the impact of resource use, waste management, and pollution prevention in the school and home environment.

6.9	The student will investigate and understand public policy decisions relating to the environment. Key concepts include a) management of renewable resources; b) management of nonrenewable resources; c) the mitigation of land-use and environmental hazards through preventive measures; and d) cost/benefit tradeoffs in conservation policies.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
• Preventive measures, such as pollution prevention or thoughtfully planned and enforced land-use restrictions, can reduce the impact of potential problems in the future. • Pollution prevention and waste management are less costly than cleanup.	



Science Standards of Learning Curriculum Framework

Life Science

Final Review
November 18, 2010

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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

School divisions should use the Science Curriculum Framework as a resource for developing sound curricular and instructional programs. Additional knowledge and skills that can enrich instruction and enhance students' understanding of the content identified in the Standards of Learning should be included as part of quality learning experiences.

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Standard LS.1

LS.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) data are organized into tables showing repeated trials and means; b) a classification system is developed based on multiple attributes; c) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and probeware are used to gather data; d) models and simulations are constructed and used to illustrate and explain phenomena; e) sources of experimental error are identified; f) dependent variables, independent variables, and constants are identified; g) variables are controlled to test hypotheses and trials are repeated; h) data are organized, communicated through graphical representation, interpreted, and used to make predictions; i) patterns are identified in data and are interpreted and evaluated; and j) current applications are used to reinforce life science concepts.
	~~**Understanding the Standard**~~ **Overview** The skills described in standard LS.1 are intended to define the "investigate" component of all of the other Life Science standards (LS.2–LS.14). The intent of standard LS.1 is that students will continue to develop a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed in the Life Science course. This does not preclude explicit instruction on a particular inquiry skill or skills, but standard LS.1 does not require a discrete unit on scientific investigation. It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science, as well as more fully grasp the content-related concepts. Models, simulations and current applications should be used throughout the course in order to learn and reinforce science concepts. Across the grade levels, kindergarten through high school, the skills in the first standards form a nearly continuous sequence. ~~(Please note Appendix, "Science Skills Scope & Sequence.")~~ It is very important that the Life Science teacher be familiar with the skills in the sequence leading up to standard LS.1 (6.1, 5.1, 4.1).

Standard LS.1

LS.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) data are organized into tables showing repeated trials and means; b) a classification system is developed based on multiple attributes; c) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and probeware are used to gather data; d) models and simulations are constructed and used to illustrate and explain phenomena; e) sources of experimental error are identified; f) dependent variables, independent variables, and constants are identified; g) variables are controlled to test hypotheses and trials are repeated; h) data are organized, communicated through graphical representation, interpreted, and used to make predictions; i) patterns are identified in data and are interpreted and evaluated; and j) current applications are used to reinforce life science concepts.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts a) the natural world is understandable; b) science is based on evidence - both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. • Expected results are reflected in the organization of ~~the~~ a data table, which includes areas to record the number of repeated trials, levels of the independent variable, measured results for the dependent variable, and analysis of the results by calculation of ~~the~~ mathematical means. • Scientists create and apply classification systems to organize information and discern patterns.	In order to meet this standard, it is expected that students ~~should be able to~~ will • make connections between the components of the nature of science and their investigations and the greater body of scientific knowledge and research. • design a data table ~~that includes space~~ to organize all components of an investigation in a meaningful way ~~including levels of the independent variable, measured responses of the dependent variable, number of trials, and mathematical means~~. • develop and use a classification system that uses numerous attributes to organize information and discern patterns. • select and use appropriate tools and techniques for collecting qualitative and quantitative data ~~and record measurements (volume, mass, and distance) in metric units~~ in classroom and field investigations. • create and use mental and physical ~~and mental~~ models (including simulations) as ways to visualize explanations of ideas and phenomena. • identify potential sources of error in the design of an experiment. • evaluate the design of an experiment and the events that occur during an investigation to determine which factors may affect the results of the experiment. This requires students to examine the experimental procedure

Standard LS.1

LS.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) data are organized into tables showing repeated trials and means; b) a classification system is developed based on multiple attributes; c) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and probeware are used to gather data; d) models and simulations are constructed and used to illustrate and explain phenomena; e) sources of experimental error are identified; f) dependent variables, independent variables, and constants are identified; g) variables are controlled to test hypotheses and trials are repeated; h) data are organized, communicated through graphical representation, interpreted, and used to make predictions; i) patterns are identified in data and are interpreted and evaluated; and j) current applications are used to reinforce life science concepts.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
• Appropriate tools and techniques are used to gather data during scientific investigations. Measurements are collected using the ~~Investigations will use~~ International System of Units (metric units) of measurement. • Mental and physical models, including computer and other simulations, can be helpful in explaining events or sequences of events that occur. They can be used as part of scientific explanations to support data or represent phenomena, especially those that are not easily seen directly or must be inferred from data. • Potential sources of error in the experimental design must be identified. • To communicate the plan of an experiment accurately, the independent variable, dependent variable, and constants must be explicitly defined. • ~~Systematic investigations require a hypothesis stated in such a way that it identifies the independent variable (parameter that is deliberately changed), the dependent variable (the response that can be measured or observed because of changes in the independent variable), and the relationship between them.~~ • To establish that the events of an experiment are the result of manipulating the independent variable, the experiment must be	and decide where or if they have made mistakes. • identify what is deliberately changed in the experiment and what is to be measured as the dependent ~~(responding)~~ variable. • analyze the variables in an experiment and decide which ones must be held constant (not allowed to change) in order for the investigation to represent a fair test. This requires students to comprehend what "variables" are and to apply that idea in new situations related to the Life Science SOL concepts. • determine the specific component of an experiment to be changed as an independent variable and control the experiment by conducting trials for the experiment in which the independent variable is *not* applied. This requires the student to set up a standard to which the experimental results can be compared. The student must use the results of the controlled trials to determine whether the hypothesized results were indeed due to the independent variable. • construct appropriate graphs, using data sets from ~~experiments~~ investigations. This requires the student to recognize that a line graph is most appropriate for reporting continuous or real-time data. This also requires a student to comprehend that points along the line that are not actual data points can be used to make predictions. Students should be able to interpret and analyze these graphs. • distinguish between observational and experimental investigations.

Standard LS.1

LS.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) data are organized into tables showing repeated trials and means; b) a classification system is developed based on multiple attributes; c) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and probeware are used to gather data; d) models and simulations are constructed and used to illustrate and explain phenomena; e) sources of experimental error are identified; f) dependent variables, independent variables, and constants are identified; g) variables are controlled to test hypotheses and trials are repeated; h) data are organized, communicated through graphical representation, interpreted, and used to make predictions; i) patterns are identified in data and are interpreted and evaluated; and j) current applications are used to reinforce life science concepts.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
controlled by observing the effects without the application of the independent variable. The results can be compared with this standard or control. Not all experiments have a control. • Multiple trials of an experiment must be conducted to verify the results. • Analysis of observed results of systematic investigations includes construction and interpretation of graphs. Such interpretation can be used to make predictions about the behavior of the dependent variable in other situations and to explore potential sources of error in the experiment. This analysis can be used to support conclusions about the results of the investigation. • Investigations can be classified as *observational* (descriptive) *studies* (intended to generate hypotheses), or *experimental studies* (intended to test hypotheses). • ~~Experimental studies sometimes follow a sequence of steps known as the Scientific Method: stating the problem, forming a hypothesis, testing the hypothesis, recording and analyzing data, stating a conclusion. However, there is no single scientific method. Science requires different abilities and procedures depending on such factors as the field of study and type of investigation.~~ • Science concepts are applied through observations and connections with everyday life and technology.	• develop conclusions based on a data set and verify whether the data set truly supports the conclusion. This requires students to cite references to the data that specifically support their conclusions. • ~~identify, describe, and apply the generalized steps of experimental (scientific) methodology.~~

Standard LS.2

LS.2	The student will investigate and understand that all living things are composed of cells. Key concepts include a) cell structure and organelles; b) similarities and differences between plant and animal cells; c) development of cell theory; and d) cell division.
	~~Understanding the Standard~~ Overview This standard builds on the general concept in science standard 5.5 that states that living things are made of cells ~~that have different parts~~. The emphasis here is on the concept that cells are the unit of structure and function of living things and on the concept of subcellular components, or organelles, each with a particular structure and function. The historical contributions of many scientists to the establishment of the cell theory are also important for students to understand. This standard also introduces students to the concept of cell division. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.2

LS.2	The student will investigate and understand that all living things are composed of cells. Key concepts include a) cell structure and organelles; b) similarities and differences between plant and animal cells; c) development of cell theory; and d) cell division.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • The structure of a cell organelle ~~reflects~~ is suited to the ~~job or~~ function carried out by that organelle. Division of labor within a cell is essential to the overall successful function of the cell. • Similarities and differences in plants and animals are evident at the cellular level. Plant and animal cells contain some of the same organelles and some that differ. • The original cell theory includes the following components: all living things are composed of cells~~,~~; cells are the smallest unit (structure) of living things that can perform the processes (functions) necessary for life~~,~~; and living cells come only from other living cells. (Although it is appropriate for students at this level to understand the three points of the original cell theory, an exploration of the revised cell theory should be reserved for high school Biology.) • The development of the original cell theory can be attributed to the major discoveries of many notable scientists. The development of the cell theory has been dependent upon improvements in the microscope and microscopic techniques throughout the last four centuries. • Continuing advances in microscopes and instrumentation have increased the understanding of cell organelles and their functions. Many of these organelles can now be observed with a ~~compound light~~ microscope (light, electron). • Cells go through a life cycle known as the cell cycle. The phases of the cell cycle are interphase, mitosis, and cytokinesis. (Although it is appropriate for students at this level to learn to recognize the stages of the cell cycle and mitosis, an exploration of the individual stages of meiosis may be reserved for high school Biology.)	In order to meet this standard, it is expected that students ~~should be able to~~ will • distinguish among the following: cell membrane, cytoplasm, nucleus, cell wall, vacuole, mitochondrion, endoplasmic reticulum, and chloroplast. • correlate the structures of cell organelles with their ~~jobs~~ functions ~~and analyze how organelles perform particular jobs~~. • compare and contrast examples of plant and animal cells, using the light microscope and images obtained from other microscopes. • describe and sequence the major points in the development of the cell theory. • identify the three components of the original cell theory. • sequence the steps in the cell cycle, including the phases of mitosis. • differentiate between the purpose of mitosis and meiosis. • design an investigation from a testable question related to animal and plant cells. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis. An example of such a question is: "Do onion cells vary in shape or structure depending on where they are found in the plant?" • ~~analyze and critique the experimental design of basic investigations related to animal and plant cells. This analysis and critique should focus on the skills developed in LS.1. Major emphases should include the following: the clarity of predictions and hypotheses, the organization of data tables, the use of metric measures, adequacy of~~

Standard LS.2

LS.2	The student will investigate and understand that all living things are composed of cells. Key concepts include a) cell structure and organelles; b) similarities and differences between plant and animal cells; c) development of cell theory; and d) cell division.
~~Overview~~ Essential Understandings	**Essential Knowledge, Skills, and Processes**
• The purpose of mitosis is to produce new cells for growth and repair that are identical to the parent cell. The purpose of meiosis is to produce reproductive (sex) cells that carry half the genetic material of the parent.	~~trials and samples, the identification and use of variables, the identification of constants, the use of controls, displays of graphical data, and the support for conclusions.~~

Standard LS.3

LS.3	The student will investigate and understand that living things show patterns of cellular organization. Key concepts include a) cells, tissues, organs, and systems; and b) patterns of cellular organization and their relationship to life processes in living things.

~~Understanding the Standard~~ Overview

This standard emphasizes the fact that among living organisms, there is a universality of the functions that maintain life. This standard continues to build upon students' knowledge of these functions and introduces students to the process of cellular transport. With the exception of the structures associated with plant reproduction, which are highlighted in 4.4, this is the students' introduction to the specific structures of plants and animals that enable them to perform life functions. Students are introduced to the concepts of unicellular and multicellular organisms and division of labor. This standard is not intended to require student understanding of the details of human body systems. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.3

LS.3	The student will investigate and understand that living things show patterns of cellular organization. Key concepts include a) cells, tissues, organs, and systems; and b) patterns of cellular organization and their relationship to life processes in living things.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • Cells that have the same function group together to form tissues. Tissues that have the same function group together to form organs. Organs with similar functions group to work together in an organ system. • Unicellular organisms are made of only one cell. Multicellular organisms are made of many cells. • Multicellular organisms exhibit a hierarchy of cellular organization. They are complex in that there is a division of labor among the levels of this hierarchy for carrying out necessary life processes. • Cells perform numerous functions and processes including cellular respiration, waste breakdown and removal, growth and division, ~~irritability~~, and ~~reproduction~~ cellular transport. • Osmosis is the passive transport of water molecules across a cell membrane. Diffusion is the passive transport of substances other than water across a cell membrane. Cell membranes are selectively permeable to various substances. (A discussion of facilitated diffusion, tonicity, and active transport should be reserved for high school Biology.) • Living things carry out life processes including ingestion, digestion and removal of waste, stimulus response, growth and repair, gas exchange, and reproduction. • Numerous factors can strongly influence the life processes of organisms.	In order to meet this standard, it is expected that students ~~should be able to~~ will • ~~differentiate~~ explain the relationship among cells, tissue, organs, and organ~~s~~ systems. • differentiate between unicellular organisms and multicellular organisms and name common examples of each. • compare and contrast how unicellular and multicellular organisms perform various life functions. This includes the application of knowledge about systems in organisms. • ~~compare and contrast the various basic life functions of an organism, including ingestion and digestion, gas exchange respiration, waste removal, growth and repair, irritability, and reproduction~~ explain the role that each life function serves for an organism: ingestion, digestion and removal of waste, stimulus response, growth and repair, gas exchange, and reproduction. • explain that there is a specific range or continuum of conditions that will meet the needs of organisms. • model how materials move into and out of cells in the processes of osmosis, diffusion, and ~~active transport~~ selective permeability. This includes creating and interpreting three-dimensional models and/or illustrations demonstrating the processes involved. Students should be able to analyze the components of these models and diagrams and communicate their observations and conclusions. • create plausible hypotheses about the effects that changes in available materials might have on particular life processes in plants and in animals. • ~~analyze and critique the experimental design of~~ conduct basic investigations related to understanding cellular organization, with

Standard LS.3

LS.3	The student will investigate and understand that living things show patterns of cellular organization. Key concepts include a) cells, tissues, organs, and systems; and b) patterns of cellular organization and their relationship to life processes in living things.
~~Overview~~ Essential Understandings	**Essential Knowledge, Skills, and Processes**
	emphasis on observations of cells and tissue. This ~~analysis and critique~~ investigation should focus on the skills developed in LS.1. ~~Major emphases should include the following: the clarity of predictions and hypotheses, the organization of data tables, the use of metric measures, adequacy of trials and samples, the identification and use of variables, the identification of constants, the use of controls, displays of graphical data, and the support for conclusions.~~

Standard LS.4

LS.4	The student will investigate and understand how organisms can be classified. Key concepts include a) the distinguishing characteristics of domains of organisms; b) the distinguishing characteristics of kingdoms of organisms; c) the distinguishing characteristics of major animal phyla and plant divisions; and d) the characteristics that define a species.
	~~Understanding the Standard~~ Overview Classifying and grouping is a key inquiry skill, as described in the K–12 "Investigate and Understand" section of the Introduction to the *Science Standards of Learning.* Classifying is an important skill in the K–6 "Scientific Investigation, Reasoning and Logic" strand. The use of a classification key is introduced in 5.1. A key concept of 5.5 is the idea of using characteristics to group organisms into the currently recognized kingdoms. This standard focuses on students continuing to practice classification skills within a hierarchical biological classification system. This is accomplished by analyzing similarities and differences between the structures and functions of organisms. Students should understand that scientists use classification as a tool to organize information about organisms and to gain information about related organisms. This standard does not require a detailed survey of each domain, kingdom or phylum, but rather a general overview of how organisms are grouped and a focus on a few key groups. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.4

LS.4	The student will investigate and understand how organisms can be classified. Key concepts include a) the distinguishing characteristics of domains of organisms; b) the distinguishing characteristics of kingdoms of organisms; c) the distinguishing characteristics of major animal phyla and plant divisions; and d) the characteristics that define a species.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • Information about physical features and activities is arranged in a hierarchy of increasing specificity. The levels in the accepted hierarchy include domain, kingdom, phylum, class, order, family, genus and species. • Current classification systems now generally recognize the categorization of organisms into three domains, Archaea, Bacteria and Eukarya. • As living things are constantly being investigated, new attributes (physical and chemical) are revealed that affect how organisms are placed in a standard classification system. This system is the basis for scientific binomial nomenclature. • Any grouping of organisms into domains or kingdoms is based on several factors, including the presence or absence of cellular structures, such as the nucleus, mitochondria, or a cell wall; whether the organisms exist as single cells or are multicellular; and how the organisms get their food. For example, simple, single-celled organisms that are able to survive in extreme environments ~~do not have a nucleus~~ are believed to be fundamentally different from other organisms and may be classified in ~~one or even two different kingdoms~~ their own domain (Archaea). ~~Six~~ Four different kingdoms of the Eukarya domain of organisms are generally recognized by scientists today (Protista, Fungi, Plants, and Animals). • Some important animal groups (phyla) are the cnidarians, mollusks, annelids, arthropods, echinoderms, and chordates. • Four important plant groups (divisions) are the mosses, ferns, conifers, and flowering plants.	In order to meet this standard, it is expected that students ~~should be able to~~ will • ~~compare and contrast key features and activities between organisms.~~ • classify organisms based on a comparison of key physical features and activities. • arrange organisms in a hierarchy according to similarities and differences in features. • categorize examples of organisms as representative of the kingdoms and recognize that the number of kingdoms is subject to change as new data are collected. • categorize examples of organisms as representative of the three domains (Archaea, Bacteria and Eukarya) and recognize that the number of domains is subject to change as new data are collected. • ~~recognize that the number of kingdoms is subject to change.~~ • recognize examples of major animal phyla. • recognize examples of major plant ~~phyla~~ ~~(~~divisions~~)~~. • recognize scientific names as part of a binomial nomenclature.

Standard LS.4

LS.4	The student will investigate and understand how organisms can be classified. Key concepts include a) the distinguishing characteristics of domains of organisms; b) the distinguishing characteristics of kingdoms of organisms; c) the distinguishing characteristics of major animal phyla and plant divisions; and d) the characteristics that define a species.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
• A group of similar-looking organisms that can interbreed under natural conditions and produce offspring that are capable of reproduction defines a species.	

Standard LS.5

LS.5	The student will investigate and understand the basic physical and chemical processes of photosynthesis and its importance to plant and animal life. Key concepts include a) energy transfer between sunlight and chlorophyll; b) transformation of water and carbon dioxide into sugar and oxygen; and c) photosynthesis as the foundation of virtually all food webs.
	~~Understanding the Standard~~ Overview Students learn in 4.4 that photosynthesis is a basic life process of plants requiring chlorophyll and carbon dioxide. This standard pulls these ideas together to demonstrate the complexity and importance of photosynthesis. Energy enters food webs through photosynthesis and is then transferred throughout the food web. It is crucial that students understand the importance of plants (and other photosynthesizing organisms) in this role of providing energy to all other living things. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.5

LS.5	The student will investigate and understand the basic physical and chemical processes of photosynthesis and its importance to plant and animal life. Key concepts include a) energy transfer between sunlight and chlorophyll; b) transformation of water and carbon dioxide into sugar and oxygen; and c) photosynthesis as the foundation of virtually all food webs.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • Chlorophyll is a chemical in chloroplasts that can absorb or trap light energy. • Photosynthesis is the necessary life process that transforms light energy into chemical energy. It involves a series of chemical reactions in which the light energy is used to change raw materials (carbon dioxide and water) into products (sugar and oxygen). The energy is stored in the chemical bonds of the glucose (sugar) molecules. • Plants perform cellular respiration as well as photosynthesis. • Plants convert the sugars they produce into other raw materials that are used by plants and animals for growth, repair, and energy needs. • Energy is a basic need of all living things. Photosynthesizing organisms obtain their energy from the sun~~. Plants and other photosynthesizing organisms~~ and are often called producers because of their ability to produce glucose (sugar). • Photosynthesizing organisms are ~~at the base of the energy pyramid~~ the foundation of virtually all food webs.	In order to meet this standard, it is expected that students ~~should be able to~~ will • describe the process of photosynthesis in terms of raw materials and products generated. • identify and describe the cellular organelles involved in the process of photosynthesis. • explain how organisms utilize the energy stored from the products of photosynthesis. • compare and contrast the processes of photosynthesis and cellular respiration. • relate the importance of photosynthesis to the role of producers as the foundation of food webs. • design an investigation from a testable question related to photosynthesis. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis. • ~~analyze and critique the experimental design of basic investigations related to photosynthesis. This analysis and critique should focus on the skills developed in LS.1. Major emphases should include the following: the clarity of predictions and hypotheses, the organization of data tables, the use of metric measures, adequacy of trials and samples, the identification and use of variables, the identification of constants, the use of controls, displays of graphical data, and the support for conclusions.~~

Standard LS.6

LS.6	The student will investigate and understand that organisms within an ecosystem are dependent on one another and on nonliving components of the environment. Key concepts include a) the carbon, water, and nitrogen cycles; b) interactions resulting in a flow of energy and matter throughout the system; c) complex relationships within terrestrial, freshwater, and marine ecosystems; and d) energy flow in food webs and energy pyramids.
	~~Understanding the Standard~~ Overview This standard explores the *application* of the concept of interdependence between organisms and their physical environment. This concept is covered thoroughly in the K–6 standards of the Living Systems strand. The K–6 standards include the concept of interdependence (2.5)~~,~~; relationships in aquatic and terrestrial food chains, trophic levels ~~(3.5 and 6.9),~~ food webs, food pyramids and cycles (~~6.9~~ 3.5 and 4.5)~~,~~; and interactions between the living and nonliving components of an ecosystem (4.5). Terminology used in previous standards includes producer, consumer, decomposer ~~(3.5 and 6.9)~~, herbivore, omnivore, carnivore (3.5), and niche (4.5). It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.6

LS.6	The student will investigate and understand that organisms within an ecosystem are dependent on one another and on nonliving components of the environment. Key concepts include a) the carbon, water, and nitrogen cycles; b) interactions resulting in a flow of energy and matter throughout the system; c) complex relationships within terrestrial, freshwater, and marine ecosystems; and d) energy flow in food webs and energy pyramids.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • Many important elements and compounds cycle through the living and nonliving components of the environment as a chain of events that continuously repeats. • Materials are recycled and made available through the action of decomposers. • In order to understand how an ecosystem functions, one must understand the concept of a system and be able to envision models of systems. • To analyze the interactions resulting in a flow of energy and matter throughout the ecosystem, one must identify the elements of the system and interpret how energy and matter are used by each organism. • Energy enters an ecosystem through the process of photosynthesis and is passed through the system as one organism eats and is, in turn, eaten. This energy flow can be modeled through relationships expressed in food webs. • The amount of energy available to each successive trophic level (producer, first-order consumer, second-order consumer, third-order consumer) decreases. This can be modeled through an energy pyramid, in which the producers provide the broad base that supports the other interactions in the system.	In order to meet this standard, it is expected that students ~~should be able to~~ will • differentiate among key processes in the water, carbon, and nitrogen cycles and ~~analyze~~ relate how organisms, from bacteria and fungi to third-order consumers, function in these cycles. • observe and identify common organisms in ecosystems and collect, record, and chart data concerning the interactions of these organisms (from observations and print and electronic resources). • classify organisms found in local ecosystems as producers or first-, second-, or third-order consumers. Design and construct models of food webs with these organisms. • observe local ecosystems and identify, measure, and classify the living and nonliving components. • identify examples of interdependence in terrestrial, freshwater, and marine ecosystems. • determine the relationship between a population's position in a food web and its size. • apply the concepts of food chains, food webs, and energy pyramids to analyze how energy and matter flow through an ecosystem. • design an investigation from a testable question related to food webs. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis. • analyze and critique the experimental design of basic investigations

Standard LS.6

LS.6	The student will investigate and understand that organisms within an ecosystem are dependent on one another and on nonliving components of the environment. Key concepts include a) the carbon, water, and nitrogen cycles; b) interactions resulting in a flow of energy and matter throughout the system; c) complex relationships within terrestrial, freshwater, and marine ecosystems; and d) energy flow in food webs and energy pyramids.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
	related to food webs.

Standard LS.7

LS.7	The student will investigate and understand that interactions exist among members of a population. Key concepts include a) competition, cooperation, social hierarchy, territorial imperative; and b) influence of behavior on a population.

~~Understanding the Standard~~ Overview

This standard applies the concept that each organism exists as a member of a population and interacts with other members of that population in a variety of ways. The term population is introduced in standard 3.6 ("Living Systems" strand). Individuals of a population demonstrate various behavioral adaptations (competition, cooperation, establishment of a social hierarchy, territorial imperative), which allow the population to survive. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.7

LS.7	The student will investigate and understand that interactions exist among members of a population. Key concepts include a) competition, cooperation, social hierarchy, territorial imperative; and b) influence of behavior on a population.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • Individual members of a population interact with each other. These interactions include competing with each other for basic resources, mates, ~~and~~ territory, and cooperating with each other to meet basic needs. • The establishment of a social order in a population may ~~insure~~ ensure that labor and resources are adequately shared. • The establishment of a territory ensures that members of a population have adequate habitat to provide for basic resources. • Individual behaviors and group behaviors can influence a population. • Animals exhibit needs for food, water, gases, shelter and space for which they compete. These needs may often be met in a range of conditions. Too much may be as harmful as too little (e.g., too much food or too little water).	In order to meet this standard, it is expected that students ~~should be able to~~ will • differentiate between the needs of the individual and the needs of a population. • interpret, analyze, and evaluate data from systematic studies and experiments concerning the interactions among members of a population. • determine the relationship between a population's position in a food web and the types of interactions seen among the individuals of the population. • observe and identify populations in ecosystems and collect, record, chart, and interpret data concerning the interactions of these organisms (from observations and print and electronic resources). • categorize behaviors as examples of competition, cooperation, social hierarchy, or territorial imperative. • ~~analyze and critique the experimental design of basic investigations related to interactions within a population. This analysis and critique should focus on the skills developed in LS.1. Major emphases should include the following: the clarity of predictions and hypotheses, the organization of data tables, the use of metric measures, adequacy of trials and samples, the identification and use of variables, the identification of constants, the use of controls, displays of graphical data, and the support for conclusions.~~

Standard LS.8

LS.8	The student will investigate and understand interactions among populations in a biological community. Key concepts include a) the relationships among producers, consumers, and decomposers in food webs; b) the relationship between predators and prey; c) competition and cooperation; d) symbiotic relationships; and e) niches.
	~~Understanding the Standard~~ Overview Life Science standard LS.~~9~~8 applies the concept of interactions between populations of different species. This standard extends the concepts of prior K–6 standards, including those concerning producers, consumers, and decomposers (3.5); predator and prey (3.6); and niches (4.5). This standard introduces the concept of symbiosis and focuses on the symbiotic relationship between parasite and host. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.8

LS.8	The student will investigate and understand interactions among populations in a biological community. Key concepts include a) the relationships among producers, consumers, and decomposers in food webs; b) the relationship between predators and prey; c) competition and cooperation; d) symbiotic relationships; and e) niches.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • Organisms or populations that rely on each other for basic needs form interdependent communities. • Energy resources of a community are shared through the interactions of producers, consumers, and decomposers. • The interaction between a consumer that hunts for another consumer for food is the predator-prey relationship. • In a community, populations interact with other populations by exhibiting a variety of behaviors that aid in the survival of the population. • Organisms may exist as members of a population; populations interact with other populations in a community~~; and communities together with the physical environment form ecosystems~~. • Populations of one species may compete with populations of other species for resources. Populations of one species may also cooperate with populations of other species for resources. • A symbiotic relationship may exist between two or more organisms of different species when they live and work together. • Symbiotic relationships include mutualism (in which both organisms benefit), commensalism (in which one organism benefits and the other is unaffected), and parasitism (in which one organism benefits and the other is harmed). • Each organism fills a specific role or niche in its community.	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify the populations of producers, consumers, and decomposers and describe the roles they play in their communities. • interpret, analyze, and evaluate data from systematic studies and experiments concerning the interactions of populations in an ecosystem. • predict the effect of population changes on the food web of a community. • generate predictions based on graphically represented data of predator-prey populations. • generate predictions based on graphically represented data of competition and cooperation between populations. • differentiate between the types of symbiosis and explain examples of each. • infer the niche of organisms from their physical characteristics. • design an investigation from a testable question related to interactions among populations. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis.

Standard LS.9

LS.9	The student will investigate and understand how organisms adapt to biotic and abiotic factors in an ecosystem. Key concepts include a) differences between ecosystems and biomes; b) characteristics of land, marine, and freshwater ecosystems; and c) adaptations that enable organisms to survive within a specific ecosystem.
	~~Understanding the Standard~~ Overview In standard LS.~~10~~9, students explore the scheme of the Earth as a group of living systems. Students are asked to distinguish between ecosystems and biomes. The teacher should be aware that in previous standards, students have explored environments as discrete units or have examined individual components. In standard 3.6 students are introduced to the concept of water environments (pond, marshland, swamp, stream, river, and ocean) and land environments (desert, grassland, rainforest, and forest). It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.9

LS.9	The student will investigate and understand how organisms adapt to biotic and abiotic factors in an ecosystem. Key concepts include a) differences between ecosystems and biomes; b) characteristics of land, marine, and freshwater ecosystems; and c) adaptations that enable organisms to survive within a specific ecosystem.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • The living organisms within a specific area and their physical environment define an ecosystem. • Characteristics of land, marine, and freshwater ecosystems vary with respect to biotic and abiotic factors. • The major terrestrial ecosystems are classified into units called biomes — large regions characterized by certain conditions, including a range of climate and ecological communities adapted to those conditions. • Organisms have specific structures, functions, and behaviors that enable them to survive the biotic and abiotic conditions of the particular ecosystem in which they live. • Organisms ~~adapt~~ possess adaptations to both biotic and abiotic factors in their ecosystem that increase their chance of survival.	In order to meet this standard, it is expected that students ~~should be able to~~ will • differentiate between ecosystems and biomes. • recognize and give examples of major biomes: desert, forest, grassland, and tundra. • compare and contrast the biotic and abiotic characteristics of land, marine, and freshwater ecosystems. • ~~observe and describe examples of specific adaptations that organisms have which enable them to survive in a particular ecosystem.~~ • analyze and describe how specific adaptations enable ~~of~~ organisms to ~~determine how they help the species~~ survive in ~~it's~~ a particular ecosystem. • design an investigation from a testable question related to how specific adaptations of organisms allow them to survive in the presence of the ~~adapt to~~ biotic and abiotic factors in an ecosystem~~s~~. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis. • ~~analyze and critique the experimental design of basic investigations related to how organisms adapt to biotic and abiotic factors in ecosystems.~~

Standard LS.10

LS.10	The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic, change over time, and respond to daily, seasonal, and long-term changes in their environment. Key concepts include a) phototropism, hibernation, and dormancy; b) factors that increase or decrease population size; and c) eutrophication, climate changes, and catastrophic disturbances.
	~~Understanding the Standard~~ Overview In standard LS.~~11~~10, students apply the concept of change over time to several specific situations. As conditions change, organisms, populations, communities, and ecosystems respond to those changes in order to survive. The key concepts are given in a sequence from responses of individual organisms (phototropism, hibernation, and dormancy) to responses of populations (factors that increase or decrease population size) to responses of communities or ecosystems (eutrophication, climate change, and catastrophic disturbances). The concepts of standard LS.~~11~~10 focus on the theme of change. Living units respond in various ways to change. A key concept is the understanding of the dynamic nature of living systems as they constantly respond to change. Change is referenced several times in the K–6 standards. In the "Earth Patterns, Cycles, and Change" strand, the following concepts are introduced: natural and human-made things may change over time (K.~~9~~10); temperature, light, and precipitation bring about changes (1.7); and weather and seasonal changes affect plants, animals, and their surroundings (2.7). ~~In t~~The "Life Processes" strand, ~~the following concepts are introduced: animals respond to life needs through hibernation, migration, camouflage, etc. (3.4); and basic plant processes include the responses of reproduction, photosynthesis, dormancy~~ introduces the concept that plants (3.4) and animals (4.4) satisfy life needs and respond to the environment. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.10

LS.10	The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic, change over time, and respond to daily, seasonal, and long-term changes in their environment. Key concepts include a) phototropism, hibernation, and dormancy; b) factors that increase or decrease population size; and c) eutrophication, climate changes, and catastrophic disturbances.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • Organisms may exist as members of a population; populations interact with other populations in a community; and communities together with the physical environment form ecosystems. • Changes that affect organisms over time may be daily, seasonal, or long-term. • Plants may respond to light by growing toward it or away from it, a behavior known as phototropism. • Animals may respond to cold conditions with a period of lowered metabolism, a behavior known as hibernation. • Organisms may respond to adverse conditions with a period of lowered or suspended metabolism, a behavior known as dormancy. • A variety of environmental factors may cause the size of a population to increase or decrease. (This requires students to brainstorm examples of factors and predict the possible effects.) • ~~Large-scale~~ Long-term changes may affect entire communities and ecosystems. Such large-scale changes include the addition of excess nutrients to the system (eutrophication), which alters environmental balance; dramatic changes in climate; and catastrophic events, such as fire, drought, flood, and earthquakes.	In order to meet this standard, it is expected that students ~~should be able to~~ will • relate the responses of organisms to daily, seasonal, or long-term events. • differentiate between ecosystems, communities, populations, and organisms. • predict the effect of climate change on ecosystems, communities, populations, and organisms. • predict the effect of ~~large scale changes~~ eutrophication on ecosystems, communities, populations, and organisms. • compare and contrast the factors that increase or decrease population size. • classify the various types of changes that occur over time in ecosystems, communities, populations, and organisms, as long term, short term, or seasonal. • design an investigation from a testable question related to change over time in ecosystems, communities, populations, or organisms. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis. • analyze and critique the experimental design of basic investigations related to change over time in ecosystems, communities, populations, and organisms.

Standard LS.11

LS.11	The student will investigate and understand the relationships between ecosystem dynamics and human activity. Key concepts include a) food production and harvest; b) change in habitat size, quality, or structure; c) change in species competition; d) population disturbances and factors that threaten or enhance species survival; and e) environmental issues.
	~~Understanding the Standard~~ Overview In this standard, students are called upon to apply their knowledge of human interactions to interpret how these interactions affect ecosystem dynamics. In prior standards in the "Resources" strand of the K–6 standards, students explore a variety of ways in which humans interact with the environment. These include the concepts of waste management (K.~~10~~11, 1.8)~~,~~; limitations of natural resources and factors that affect environmental quality (1.8, 3.10)~~,~~; Virginia's natural resources (4.8)~~,~~; and public policy decisions relating to the environment (6.9). In this Life Science standard, the student must interpret how human populations can change the balance of nature in ecosystems. They must use their prior knowledge of resources as well as the concepts and skills learned in Life Science standards ~~LS.7 – LS.11~~ LS.6 – LS.10. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.11

LS.11	The student will investigate and understand the relationships between ecosystem dynamics and human activity. Key concepts include a) food production and harvest; b) change in habitat size, quality, or structure; c) change in species competition; d) population disturbances and factors that threaten or enhance species survival; and e) environmental issues.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • Ecosystems are dynamic systems. Humans are a natural part of the ecosystem. Humans use the ecosystem to meet their basic needs, such as to obtain food. • Human interaction can directly alter habitat size, the quality of available resources in a habitat, and the structure of habitat components. Such interactions can be positive and/or negative. • Human input can disturb the balance of populations that occur in a stable ecosystem. These disturbances may lead to a decrease or increase in a population. Since populations in an ecosystem are interdependent, these disturbances have a ripple effect throughout the ecosystem. • The interaction of humans with the dynamic ecosystem may lead to issues of concern for continued ecosystem health in areas such as water supply, air quality, energy production, and waste management.	In order to meet this standard, it is expected that students ~~should be able to~~ will • identify examples of ecosystem dynamics. • describe the relationship between human food harvest and the ecosystem. • debate the pros and cons of human land use versus ecosystem stability. • compare and contrast population disturbances that threaten and those that enhance species survival. • describe ways that human interaction has altered habitats positively and negatively. • observe the effect of human interaction in local ecosystems and collect, record, chart, and interpret data concerning the effect of interaction (from observations and print and electronic resources). • design an investigation from a testable question related to the relationships between ecosystem dynamics and human activity. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis. • analyze and critique the experimental design of basic investigations related to the relationships between ecosystem dynamics and human activity.

Standard LS.12

LS.12	The student will investigate and understand that organisms reproduce and transmit genetic information to new generations. Key concepts include a) the structure and role of DNA; b) the function of genes and chromosomes; c) genotypes and phenotypes; d) characteristics that can and cannot be inherited; e) genetic engineering and its applications; and f) historical contributions and significance of discoveries related to genetics.
	~~Understanding the Standard~~ Overview In science standard 2.7, students are introduced to the general notion that plants and animals resemble their parents. This Life Science standard is the students' introduction to genetics. It is important for the teacher to understand that the intent of this standard is to provide students with a general overview of the nature of DNA, genes, and chromosomes and the important role they play in the transmission of traits from one generation to another. Students are not expected to understand the specific chemical composition of DNA or the mechanics of transcription and translation. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.12

LS.12	The student will investigate and understand that organisms reproduce and transmit genetic information to new generations. Key concepts include a) the structure and role of DNA; b) the function of genes and chromosomes; c) genotypes and phenotypes; d) characteristics that can and cannot be inherited; e) genetic engineering and its applications; and f) historical contributions and significance of discoveries related to genetics.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • DNA is a double helix molecule. • DNA is a molecule that includes different components — sugars, nitrogenous bases, and phosphates. The arrangement of the nitrogenous bases within the double helix forms a chemical code. • Chromosomes are strands of tightly wound DNA. Genes are sections of a chromosome that carry the code for a particular trait. An allele is an alternate form of a gene. • The basic laws of Mendelian genetics explain the transmission of most traits that can be inherited from generation to generation. • A Punnett square is a model used to predict the possible combinations of inherited factors resulting from single trait crosses. (An investigation of dihybrid crosses, multiple alleles, and incomplete dominance should be reserved for high school Biology.) • Dominant traits mask the expression (phenotype) of recessive traits. Genotype is the specific combination of dominant and recessive gene forms. • Traits that are expressed through genes can be inherited. Characteristics that are acquired through environmental influences, such as injuries or practiced skills, cannot be inherited. • In genetic engineering, the genetic code is manipulated to obtain a desired product. • Genetic engineering has numerous practical applications in medicine,	In order to meet this standard, it is expected that students ~~should be able to~~ will • recognize the appearance of DNA as double helix in shape. • explain that DNA contains coded instructions that store and pass on genetic information from one generation to the next. • explain the necessity of DNA replication for the continuity of life. • explain the relationship ~~between~~ among genes, chromosomes, and alleles. • demonstrate variation within a single genetic trait. • distinguish between dominant and recessive traits. • distinguish between genotype and phenotype. • use Punnett squares to predict the possible combinations of inherited factors resulting from single trait crosses. • differentiate between characteristics that can be inherited and those that cannot be inherited. • identify aspects of genetic engineering and supply examples of applications. Evaluate the examples for possible controversial aspects. • describe the contributions of Mendel, Franklin, ~~and~~ Watson, and Crick to our basic understanding of genetics.

Standard LS.12

LS.12	The student will investigate and understand that organisms reproduce and transmit genetic information to new generations. Key concepts include a) the structure and role of DNA; b) the function of genes and chromosomes; c) genotypes and phenotypes; d) characteristics that can and cannot be inherited; e) genetic engineering and its applications; and f) historical contributions and significance of discoveries related to genetics.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
agriculture, and biology. • A series of contributions and discoveries led to the current level of genetic science.	

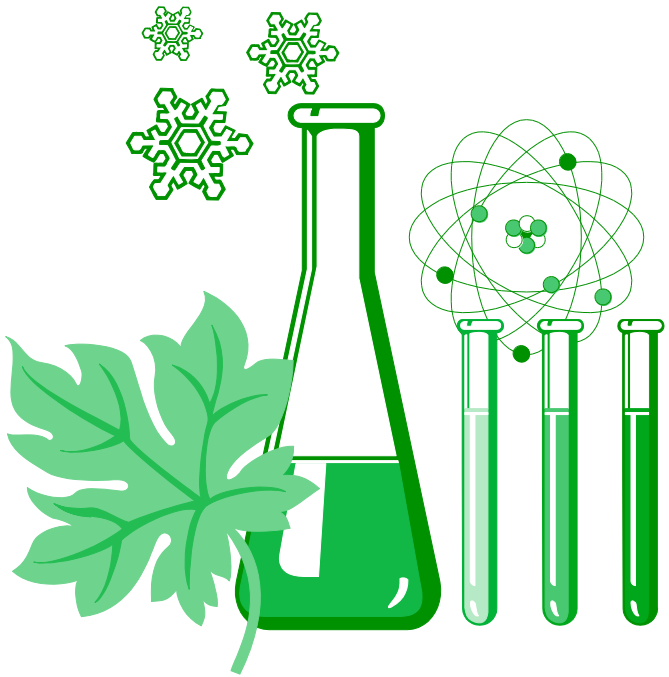
Standard LS.13

LS.13	The student will investigate and understand that populations of organisms change over time. Key concepts include a) the relationships of mutation, adaptation, natural selection, and extinction; b) evidence of evolution of different species in the fossil record; and c) how environmental influences, as well as genetic variation, can lead to diversity of organisms.
	~~Understanding the Standard~~ Overview Standard LS.~~14~~13 explores the concept of evolution through natural selection. Species respond to changes in their environments through adaptations~~. This~~ and is a gradual process that occurs over long periods of time. The progression of these long-term changes is well documented in the fossil record. Evolution, as a big organizing principle of the life sciences, establishes order among the great variety of living things. There are many misconceptions about evolution; therefore, teachers must be careful to be accurate in their presentation of this scientific theory. One common misconception among students is that they believe that environmental influences on an organism produce changes in that organism that can be passed on to offspring. However, natural selection can only work through the genetic variation that is already present in the population. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (LS.1) in the context of the key concepts presented in this standard.

Standard LS.13

LS.13	The student will investigate and understand that populations of organisms change over time. Key concepts include a) the relationships of mutation, adaptation, natural selection, and extinction; b) evidence of evolution of different species in the fossil record; and c) how environmental influences, as well as genetic variation, can lead to diversity of organisms.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The concepts developed in this standard include the following: • The mechanisms through which evolution takes place are a related set of processes that include mutation, adaptation, natural selection, and extinction. This results in changes in populations of organisms over time. • Mutations are inheritable changes because a mutation is a change in the DNA code. • Adaptations are structures, functions, or behaviors that enable a species to survive. • Natural selection is the survival and reproduction of the individuals in a population that exhibit the traits that best enable them to survive in their environment. • A mutation may result in a favorable change or adaptation in genetic information that improves a species' ability to exist in its environment, or a mutation may result in an unfavorable change that does not improve or impedes a species' ability to exist in its environment. • The evidence for evolution is drawn from a variety of sources of data, including the fossil record, radiometric dating, genetic information, the distribution of organisms, and anatomical and developmental similarities across species. • Individuals of a population each exhibit a range of variations in a trait as a result of the variations in their genetic codes. These variations may or may not help them survive and reproduce in their environment. • If a species does not include traits that enable it to survive in its environment or to survive changes in the environment, then the species may become extinct.	In order to meet this standard, it is expected that students ~~should be able to~~ will • interpret data from simulations that demonstrate selection for a trait belonging to species in various environments. • describe how changes in the environment can bring about changes in a species (adaptation, extinction) through natural selection~~, adaptation, and extinction~~. • describe and explain how fossils are records of organisms and events in ~~the~~ Earth's history. • explain the evidence for evolution from a variety of sources of scientific data. • explain how genetic variations in offspring, which lead to variations in successive generations, can result from the same two parents. • analyze and evaluate data from investigations on variations within a local population. • explain how environmental influences, as well as genetic variation, can lead to diversity of organisms.



Science Standards of Learning Curriculum Framework

Physical Science

Final Review
November 18, 2010

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Board of Education
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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Standard PS.1

PS.1	The student will demonstrate an understanding of scientific reasoning, logic and the nature of science by planning and conducting investigations in which a) chemicals and equipment are used safely; b) length, mass, volume, density, temperature, weight, and force are accurately measured; c) conversions are made among metric units, applying appropriate prefixes; d) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, probeware, and spring scales are used to gather data; e) numbers are expressed in scientific notation where appropriate; f) independent and dependent variables, constants, controls, and repeated trials are identified; g) data tables showing the independent and dependent variables, derived quantities, and the number of trials are constructed and interpreted; h) data tables for descriptive statistics showing specific measures of central tendency, the range of the data set, and the number of repeated trials are constructed and interpreted; i) frequency distributions, scatterplots, line plots, and histograms are constructed and interpreted; j) valid conclusions are made after analyzing data; k) research methods are used to investigate practical problems and questions; l) experimental results are presented in appropriate written form; m) models and simulations are constructed and used to illustrate and explain phenomena; and n) current applications of physical science concepts are used.
	~~Understanding the Standard~~ Overview The skills described in standard PS.1 are intended to define the "investigate" component of all of the other Physical Science standards (PS.2 – PS.11). The intent of standard PS.1 is that students will continue to develop a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed in the Physical Science curriculum. Standard PS.1 does not require a discrete unit on scientific investigation because the inquiry skills that make up the standard should be incorporated in all the other Physical Science standards. It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science, as well as more fully grasp the content-related SOL concepts. Models, simulations, and current applications are used throughout the course in order to learn and reinforce science concepts. Across the grade levels, kindergarten through high school, the skills in the first standards form a nearly continuous sequence. ~~(Please note Appendix, "Science Skills Scope & Sequence.")~~ It is very important that the Physical Science teacher be familiar with the skills in the sequence leading up to standard PS.1 (LS.1, 6.1, 5.1, 4.1).

Standard PS.1

PS.1	The student will demonstrate an understanding of scientific reasoning, logic and the nature of science by planning and conducting investigations in which a) chemicals and equipment are used safely; b) length, mass, volume, density, temperature, weight, and force are accurately measured; c) conversions are made among metric units, applying appropriate prefixes; d) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, probeware, and spring scales are used to gather data; e) numbers are expressed in scientific notation where appropriate; f) independent and dependent variables, constants, controls, and repeated trials are identified; g) data tables showing the independent and dependent variables, derived quantities, and the number of trials are constructed and interpreted; h) data tables for descriptive statistics showing specific measures of central tendency, the range of the data set, and the number of repeated trials are constructed and interpreted; i) frequency distributions, scatterplots, line plots, and histograms are constructed and interpreted; j) valid conclusions are made after analyzing data; k) research methods are used to investigate practical problems and questions; l) experimental results are presented in appropriate written form; m) models and simulations are constructed and used to illustrate and explain phenomena; and n) current applications of physical science concepts are used.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The critical scientific concepts developed in this standard include the following: • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts of a) the natural world is understandable; b) science is based on evidence - both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. • Systematic investigations require standard measures and consistent and reliable tools. International System of Units (SI or metric) measures,	In order to meet this standard, it is expected that students ~~should be able to~~ will • make connections between the components of the nature of science and their investigations and the greater body of scientific knowledge and research. • select appropriate equipment (probeware, triple beam balances, thermometers, metric rulers, graduated cylinders, electronic balances, or spring scales) and utilize correct techniques to measure length, mass, density, weight, volume, temperature, and force. • design a data table that includes space to organize all components of an investigation in a meaningful way, including levels of the independent variable, measured responses of the dependent variable, number of trials, and mathematical means. • record measurements, using the following metric (SI) units: liter, milliliter (cubic centimeters), meter, centimeter, millimeter, grams, degrees Celsius, and newtons.

Standard PS.1

PS.1 The student will demonstrate an understanding of scientific reasoning, logic and the nature of science by planning and conducting investigations in which

a) chemicals and equipment are used safely;
b) length, mass, volume, density, temperature, weight, and force are accurately measured;
c) conversions are made among metric units, applying appropriate prefixes;
d) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, probeware, and spring scales are used to gather data;
e) numbers are expressed in scientific notation where appropriate;
f) independent and dependent variables, constants, controls, and repeated trials are identified;
g) data tables showing the independent and dependent variables, derived quantities, and the number of trials are constructed and interpreted;
h) data tables for descriptive statistics showing specific measures of central tendency, the range of the data set, and the number of repeated trials are constructed and interpreted;
i) frequency distributions, scatterplots, line plots, and histograms are constructed and interpreted;
j) valid conclusions are made after analyzing data;
k) research methods are used to investigate practical problems and questions;
l) experimental results are presented in appropriate written form;
m) models and simulations are constructed and used to illustrate and explain phenomena; and
n) current applications of physical science concepts are used.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
recognized around the world, are a standard way to make measurements. • Systematic investigations require organized reporting of data. The way the data are displayed can make it easier to see important patterns, trends, and relationships. Frequency distributions, ~~scattergrams~~, scatterplots, line plots, and histograms are powerful tools for displaying and interpreting data. • Investigation not only involves the careful application of systematic (scientific) methodology, but also includes the review and analysis of prior research related to the topic. Numerous sources of information are available from print and electronic sources, and the researcher needs to judge the authority and credibility of the sources. • To communicate the plan of an experiment accurately, the independent variable, dependent variable, and constants must be explicitly defined. • The number of repeated trials needs to be considered in the context of the investigation. Often "controls" are used to establish a standard for comparing the results of manipulating the independent variable. Controls receive no experimental treatment. Not all experiments have a control,	• recognize metric prefix units and make common metric conversions between the same base metric unit (for example, nanogram to milligram ~~to gram~~ or kilometer to meter). • use a variety of graphical methods to display data; create an appropriate graph for a given set of data; and select the proper type of graph for a given set of data, identify and label the axes, and plot the data points. ~~*(Note: Frequency distributions, scattergrams, line plots, and histograms are described in the Mathematics Curriculum Framework, standard 7.17, pp. 27–29.)*~~ • gather, evaluate, and summarize information, using multiple and variable resources, and detect bias from a given source. • identify the key components of controlled experiments: hypotheses, independent and dependent variables, constants, controls, and repeated trials. • formulate conclusions that are supported by the gathered data. • apply the methodology of scientific inquiry: begin with a question,

Standard PS.1

PS.1 The student will demonstrate an understanding of scientific reasoning, logic and the nature of science by planning and conducting investigations in which

a) chemicals and equipment are used safely;
b) length, mass, volume, density, temperature, weight, and force are accurately measured;
c) conversions are made among metric units, applying appropriate prefixes;
d) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, probeware, and spring scales are used to gather data;
e) numbers are expressed in scientific notation where appropriate;
f) independent and dependent variables, constants, controls, and repeated trials are identified;
g) data tables showing the independent and dependent variables, derived quantities, and the number of trials are constructed and interpreted;
h) data tables for descriptive statistics showing specific measures of central tendency, the range of the data set, and the number of repeated trials are constructed and interpreted;
i) frequency distributions, scatterplots, line plots, and histograms are constructed and interpreted;
j) valid conclusions are made after analyzing data;
k) research methods are used to investigate practical problems and questions;
l) experimental results are presented in appropriate written form;
m) models and simulations are constructed and used to illustrate and explain phenomena; and
n) current applications of physical science concepts are used.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
however. • The analysis of data from a systematic investigation may provide the researcher with a basis to reach a reasonable conclusion. Conclusions should not go beyond the evidence that supports them. Additional scientific research may yield new information that affects previous conclusions. • Different kinds of problems and questions require differing approaches and research. Scientific methodology almost always begins with a question, is based on observation and evidence, and requires logic and reasoning. Not all systematic investigations are experimental. • It is important to communicate systematically the design and results of an investigation so that questions, procedures, tools, results, and conclusions can be understood and replicated. • ~~Scientists rely on creativity and imagination during all stages of their investigations.~~ • Some useful applications of physical science concepts are in the area of materials science (e.g., metals, ceramics, semi-conductors).	design an investigation, gather evidence, formulate an answer to the original question, ~~and~~ communicate the investigative process and results~~.~~, and realize this methodology does not always follow a prescribed sequence. • communicate in written form the following information about investigations: the purpose/problem of the investigation, procedures, materials, data and/or observations, graphs, and an interpretation of the results. • describe how creativity comes into play during various stages of scientific investigations. • use current technologies to model and simulate experimental conditions. • recognize examples of the use of nanotechnology and its applications.

Standard PS.1

PS.1	The student will demonstrate an understanding of scientific reasoning, logic and the nature of science by planning and conducting investigations in which a) chemicals and equipment are used safely; b) length, mass, volume, density, temperature, weight, and force are accurately measured; c) conversions are made among metric units, applying appropriate prefixes; d) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, probeware, and spring scales are used to gather data; e) numbers are expressed in scientific notation where appropriate; f) independent and dependent variables, constants, controls, and repeated trials are identified; g) data tables showing the independent and dependent variables, derived quantities, and the number of trials are constructed and interpreted; h) data tables for descriptive statistics showing specific measures of central tendency, the range of the data set, and the number of repeated trials are constructed and interpreted; i) frequency distributions, scatterplots, line plots, and histograms are constructed and interpreted; j) valid conclusions are made after analyzing data; k) research methods are used to investigate practical problems and questions; l) experimental results are presented in appropriate written form; m) models and simulations are constructed and used to illustrate and explain phenomena; and n) current applications of physical science concepts are used.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
• Nanotechnology is the study of materials at the molecular (atomic) scale. Items at this scale are so small they are no longer visible with the naked eye. Nanotechnology has shown that the behavior and properties of some substances at the nanoscale (a nanometer is one-billionth of a meter) contradict how they behave and what their properties are at the visible scale. • New discoveries based on nanoscience investigations have allowed the production of superior new materials with improved properties (e.g., computers, cell phones).	

Standard PS.2

PS.2	The student will investigate and understand the nature of matter. Key concepts include a) the particle theory of matter; b) elements, compounds, mixtures, acids, bases, and salts; c) solids, liquids, and gases; d) physical properties; e) chemical properties; and f) characteristics of types of matter based on physical and chemical properties.
	~~Understanding the Standard~~ Overview The concepts in PS.2 build upon several science standards from previous grades, including K.4, 1.3, 2.3, 3.3, 5.4, and 6.4. These standards introduce and develop basic ideas about the characteristics and structure of matter. In PS.2, the ideas and terminology continue to be expanded and treated in greater depth, including more mathematical application. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (PS.1) in the context of the key concepts presented in this standard.

Standard PS.2

PS.2 The student will investigate and understand the nature of matter. Key concepts include

a) the particle theory of matter;
b) elements, compounds, mixtures, acids, bases, and salts;
c) solids, liquids, and gases;
d) physical properties;
e) chemical properties; and
f) characteristics of types of matter based on physical and chemical properties.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The critical scientific concepts developed in this standard include the following: • Matter is anything that has mass and occupies space. All matter is made up of small particles called atoms. Matter can exist as a solid, a liquid, ~~or~~ a gas, or plasma. • Matter can be classified as elements, compounds, and mixtures. The atoms of any element are alike but are different from atoms of other elements. Compounds consist of two or more elements that are chemically combined in a fixed ratio. Mixtures also consist of two or more substances, but the substances are not chemically combined. • Compounds can be classified in several ways, including: - acids, bases, salts - inorganic and organic compounds. • Acids make up an important group of compounds that contain hydrogen ions. When acids dissolve in water, hydrogen ions (H^+) are released into the resulting solution. A base is a substance that releases hydroxide ions (OH^-) into solution. pH is a measure of the hydrogen ion concentration in a solution. The pH scale ranges from 0–14. Solutions with a pH lower than 7 are acidic; solutions with a pH greater than 7 are basic. A pH of 7 is neutral. When an acid reacts with a base, a salt is formed, along with water. • Matter can be described by its physical properties, which include shape, density, solubility, odor, melting point, boiling point, and color. Some physical properties, such as density, boiling point, and solubility, are characteristic of a specific substance and do not depend on the size of	In order to meet this standard, it is expected that students ~~should be able to~~ will • describe the particle theory of matter. • describe how to determine whether a substance is an element, compound, or mixture. • define compounds as inorganic or organic. (All organic compounds contain carbon). • describe what a salt is and explain how salts form. • describe the properties of ~~the states of matter (~~solids, liquids, ~~and~~ gases, and plasma~~)~~. • distinguish between physical properties (i.e., shape, density, solubility, odor, melting point, boiling point, and color) and chemical properties (i.e., acidity, basicity, combustibility, and reactivity). • find the mass and volume of substances and calculate and compare their densities. • analyze the pH of a solution and classify it as acidic, basic, or neutral. • determine the identity of an unknown substance by comparing its properties to those of known substances. • design an investigation from a testable question related to physical and chemical properties of matter. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and

Standard PS.2

PS.2	The student will investigate and understand the nature of matter. Key concepts include a) the particle theory of matter; b) elements, compounds, mixtures, acids, bases, and salts; c) solids, liquids, and gases; d) physical properties; e) chemical properties; and f) characteristics of types of matter based on physical and chemical properties.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
the sample. Characteristic properties can be used to identify unknown substances. • Equal volumes of different substances usually have different masses. • Matter can also be described by its chemical properties, which include acidity, basicity, combustibility, and reactivity. A chemical property indicates whether a substance can undergo a chemical change.	analysis. (Students should be able to use the inquiry skills represented in PS.1 and LS.1 to compose a clear hypothesis, create an organized data table, identify variables and constants, record data correctly, construct appropriate graphs, analyze data, and draw reasonable conclusions.)

Standard PS.3

PS.3	The student will investigate and understand the modern and historical models of atomic structure. Key concepts include a) the contributions of Dalton, Thomson, Rutherford, and Bohr in understanding the atom; and b) the modern model of atomic structure.
	~~Understanding the Standard~~ Overview PS.3 builds upon science standards 3.3, 5.4, and 6.4, which introduce basic concepts and terminology related to the atom. PS.3 focuses more specifically on the basic structure of the atom and how models have been and are used to explain atomic structure. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (PS.1) in the context of the key concepts presented in this standard.

Standard PS.3

PS.3	The student will investigate and understand the modern and historical models of atomic structure. Key concepts include a) the contributions of Dalton, Thomson, Rutherford, and Bohr in understanding the atom; and b) the modern model of atomic structure.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The critical scientific concepts developed in this standard include the following: • Many scientists have contributed to our understanding of atomic structure. • The atom is the basic building block of matter and consists of subatomic particles (proton, neutron, ~~and~~ electron, and quark) that differ in their location, charge, and relative mass. Protons and neutrons are made up of smaller particles called quarks. • Size at the atomic level is measured on the nanoscale. • Scientists use models to help explain the structure of the atom. Their understanding of the structure of the atom continues to evolve. Two models commonly used are the Bohr and the "electron cloud" (Quantum Mechanics) models. The Bohr model does not depict the three-dimensional aspect of an atom, and it implies that electrons are in static orbits. The "electron cloud" model better represents our current understanding of the structure of the atom.	In order to meet this standard, it is expected that students ~~should be able to~~ will • describe the historical development of the concept of the atom and the contributions of Dalton, Thomson, Rutherford, ~~and~~ Bohr and other scientists (Schrödinger). • ~~use the Bohr model to~~ differentiate among the three basic particles in the atom (proton, neutron, and electron) and their charges, relative masses, and locations. • compare the Bohr atomic model to the electron cloud model with respect to ~~their~~ its ability to represent accurately the three-dimensional structure of the atom.

Standard PS.4

PS.4	The student will investigate and understand the organization and use of the periodic table of elements to obtain information. Key concepts include a) symbols, atomic number, atomic mass, chemical families (groups), and periods; b) classification of elements as metals, metalloids, and nonmetals; and c) formation of compounds through ionic and covalent bonding.
	~~Understanding the Standard~~ Overview PS.4 formally introduces the periodic table of elements. This standard builds upon concepts of the atom presented in science standard 6.4. Standard PS.4 focuses on a student's ability to look at the organization of the periodic table and obtain ~~learn what~~ information ~~can be obtained~~ from it. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (PS.1) in the context of the key concepts presented in this standard.

Standard PS.4

PS.4	The student will investigate and understand the organization and use of the periodic table of elements to obtain information. Key concepts include a) symbols, atomic number, atomic mass, chemical families (groups), and periods; b) classification of elements as metals, metalloids, and nonmetals; and c) formation of compounds through ionic and covalent bonding.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The critical scientific concepts developed in this standard include the following: • There are more than 110 known elements. No element with an atomic number greater than 92 is found naturally in measurable quantities on Earth. The remaining elements are artificially produced in a laboratory setting. Elements combine in many ways to produce compounds that make up all other substances on Earth. • The periodic table of elements is a tool used to organize information about the elements. Each box in the periodic table contains information about the structure of an element. • An atom's identity is directly related to the number of protons in its nucleus. This is the basis for the arrangement of atoms on the periodic table of elements. • The vertical columns in the table are called groups or families. ~~Elements in each group have similar properties because they have the same number of electrons in the outermost energy level~~. The horizontal rows are called periods. • Elements in the same column (family) of the periodic table contain the same number of electrons in their outer energy levels. This gives rise to their similar properties and is the basis of periodicity — the repetitive pattern of properties such as boiling point across periods on the table. • The periodic table of elements is an arrangement of elements according to atomic number and properties. The information can be used to predict chemical reactivity. The boxes for all of the elements are arranged in increasing order of atomic number. The elements have	In order to meet this standard, it is expected that students ~~should be able to~~ will • use the periodic table to obtain the following information about the atom of an element: - symbol - atomic number - atomic mass - state of matter at room temperature - number of outer energy level (valence) electrons. • describe the organization of the periodic table in terms of - atomic number - metals, metalloids, and nonmetals - groups/families vs. periods. • recognize that an atom's identity is related to the number of protons in its nucleus. • categorize a given element as metal, nonmetal, or metalloid. • given a chemical formula of a compound, identify the elements and the number of atoms of each that comprise the compound. • recognize that the number of electrons in the outermost energy level determines an element's chemical properties or chemical reactivity. • describe the difference between ionic and covalent bonding. • predict what kind of bond (ionic or covalent) will likely form when metals and nonmetals are chemically combined ~~chemically~~.

Standard PS.4

PS.4	The student will investigate and understand the organization and use of the periodic table of elements to obtain information. Key concepts include a) symbols, atomic number, atomic mass, chemical families (groups), and periods; b) classification of elements as metals, metalloids, and nonmetals; and c) formation of compounds through ionic and covalent bonding.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
an increasing nonmetallic character as one reads from left to right across the table. Along the stair-step line are the metalloids, which have properties of both metals and nonmetals. • The nonmetals are located to the right of the stair-step line on the periodic table. • Metals tend to lose electrons in chemical reactions, forming positive ions. Nonmetals tend to gain electrons in chemical reactions, forming negative ions. • Gaining or losing electrons makes an atom an ion. • Gaining or losing neutrons makes an atom an isotope. However, gaining or losing a proton makes an atom into a completely different element. • Atoms react to form chemically stable substances that are held together by chemical bonds and are represented by chemical formulas. To become chemically stable, atoms gain, lose, or share electrons. • Compounds are formed when elements react chemically. When a metallic element reacts with a nonmetallic element, their atoms gain and lose electrons respectively, forming ionic bonds. Generally, when two nonmetals react, atoms share electrons, forming covalent (molecular) bonds.	

Standard PS.5

PS.5	The student will investigate and understand changes in matter and the relationship of these changes to the Law of Conservation of Matter and Energy. Key concepts include a) physical changes; b) chemical changes; and c) nuclear reactions.
	~~Understanding the Standard~~ Overview This standard focuses on the concept that matter and energy can be changed in different ways, but the total amount of mass and energy is conserved. Students have previously investigated physical and chemical changes. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (PS.1) in the context of the key concepts presented in this standard.

Standard PS.5

PS.5	The student will investigate and understand changes in matter and the relationship of these changes to the Law of Conservation of Matter and Energy. Key concepts include a) physical changes; b) chemical changes; and c) nuclear reactions.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The critical scientific concepts developed in this standard include the following: • Matter can undergo physical and chemical changes. In physical changes, the chemical composition of the substances does not change. In chemical changes, different substances are formed. Chemical changes are often affected by the surface area/volume ratio of the materials involved in the change. • The Law of Conservation of Matter (Mass) states that regardless of how substances within a closed system are changed, the total mass remains the same. The Law of Conservation of Energy states that energy cannot be created or destroyed but only changed from one form to another. • A chemical equation represents the changes that take place in a chemical reaction. The chemical formulas of the reactants are written on the left, an arrow indicates a change to new substances, and the chemical formulas of the products are written on the right. Chemical reactions are classified into two broad types: ones in which energy is released (exothermic) and ones in which energy is absorbed (endothermic). (The study of synthesis, decomposition, and replacement reactions can be reserved for high school ~~C~~chemistry.) • Another type of change occurs in nuclear reactions. Nuclear energy is the energy stored in the nucleus of an atom. This energy can be released by joining nuclei together (fusion) or by splitting nuclei (fission), resulting in the conversion of minute amounts of matter into energy. In nuclear reactions, a small amount of matter produces a large amount of energy. However, there are potential negative effects of using nuclear energy, including radioactive nuclear waste storage and disposal.	In order to meet this standard, it is expected that students ~~should be able to~~ will • compare and contrast physical, chemical, and nuclear changes. • identify the reactants and products in a given chemical equation formula. • design an investigation that illustrates physical and chemical changes. • given chemical formulas, write and balance simple chemical equations. • analyze experimental data to determine whether it supports the Law of Conservation of Mass. • recognize that some types of chemical reactions require continuous input of energy (endothermic) and others release energy (exothermic). • describe, in simple terms, the processes that release nuclear energy (i.e., nuclear fission and nuclear fusion). Create a simple diagram to summarize and compare and contrast these two types of nuclear energy. • evaluate the positive and negative effects of using nuclear energy.

Standard PS.6

PS.6	The student will investigate and understand forms of energy and how energy is transferred and transformed. Key concepts include a) potential and kinetic energy; and b) mechanical, chemical, electrical, thermal, radiant and nuclear energy.
	~~Understanding the Standard~~ Overview The concepts in PS.6 build upon several science standards from previous grades, including 4.2, 4.3, ~~5.3~~, 6.~~3~~2, and 6.4. These standards introduce and develop basic ideas about states and forms of energy. At the sixth-grade level, this sequence culminates with the idea about energy transformations. In PS.6, concepts about energy forms, energy transformations, and potential and kinetic energy continue to be expanded and treated in greater depth, including more mathematical application. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (PS.1) in the context of the key concepts presented in this standard.

Standard PS.6

PS.6	The student will investigate and understand forms of energy and how energy is transferred and transformed. Key concepts include a) potential and kinetic energy; and b) mechanical, chemical, electrical, thermal, radiant and nuclear energy.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The critical scientific concepts developed in this standard include the following: • Energy is the ability to do work. • Energy exists in two states. Potential energy is stored energy based on position or chemical composition. Kinetic energy is energy of motion. Students should know that the amount of potential energy associated with an object depends on its position. The amount of kinetic energy depends on the mass and velocity of the moving object. • Important forms of energy include ~~light~~ radiant, ~~heat~~ thermal, chemical, electrical, mechanical, and nuclear energy. Visible light is a form of radiant energy and ~~S~~sound is a form of mechanical energy. • Energy can be transformed from one type to another. In any energy conversion, some of the energy is lost to the environment as ~~heat~~ thermal energy.	In order to meet this standard, it is expected that students ~~should be able to~~ will • differentiate between potential and kinetic energy. • use diagrams or concrete examples to compare relative amounts of potential and kinetic energy. • identify and give examples of common forms of energy. • design an investigation or create a diagram to illustrate energy transformations.

Standard PS.7

PS.7	The student will investigate and understand temperature scales, heat, and thermal energy transfer. Key concepts include a) Celsius and Kelvin temperature scales and absolute zero; b) phase change, freezing point, melting point, boiling point, vaporization, and condensation; c) conduction, convection, and radiation; and d) applications of thermal energy transfer.
	~~Understanding the Standard~~ Overview This standard focuses on how ~~heat affects matter and how heat~~ thermal energy is transferred. Concepts introduced in previous grades and related to the states of matter are presented in standards 2.3 and 5.4. More complex concepts and terminology related to phase changes are introduced in PS.7, including the distinction between heat and temperature. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (PS.1) in the context of the key concepts presented in this standard.

Standard PS.7

PS.7 The student will investigate and understand temperature scales, heat, and thermal energy transfer. Key concepts include

a) Celsius and Kelvin temperature scales and absolute zero;
b) phase change, freezing point, melting point, boiling point, vaporization, and condensation;
c) conduction, convection, and radiation; and
d) applications of thermal energy transfer.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The critical scientific concepts developed in this standard include the following: • Heat and temperature are not the same thing. Heat is the transfer of thermal energy between substances of different temperature. As thermal energy is added, the temperature of a substance increases. • Temperature is a measure of the average kinetic energy of the molecules of a substance. Increased temperature means greater average kinetic energy of the molecules in the substance being measured, and most substances expand when heated. The temperature of absolute zero (–273°C/0°K) is the theoretical point at which molecular motion stops. • Atoms and molecules are perpetually in motion. • The transfer of ~~heat~~ thermal energy occurs in three ways: by conduction, by convection, and by radiation. • As ~~heat~~ thermal energy is added to or taken away from a system, the temperature does not always change. There is no change in temperature during a phase change (freezing, melting, condensing, evaporation, boiling, and vaporizing) as this energy is being used to make or break bonds between molecules.	In order to meet this standard, it is expected that students ~~should be able to~~ will • distinguish between heat and temperature. • compare and contrast Celsius and Kelvin temperature scales and describe absolute zero. • illustrate and explain the effect of the addition or subtraction of heat thermal energy on the motion of molecules. • analyze a time/temperature graph of a phase change experiment to determine the temperature at which the phase change occurs (freezing point, melting point, or boiling point). • compare and contrast methods of thermal energy transfer (conduction, convection, and radiation) and provide and explain common examples. • explain, in simple terms, how the principle of ~~heat~~ thermal energy transfer applies to heat engines, thermostats, ~~and~~ refrigerators, ~~and~~ heat pumps, and geothermal systems. • design an investigation from a testable question related to ~~heat~~ thermal energy transfer. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis.

Standard PS.8

PS.8	The student will investigate and understand the characteristics of sound waves. Key concepts include a) wavelength, frequency, speed, amplitude, rarefaction, and compression; b) resonance; c) the nature of compression waves; and d) technological applications of sound.
	~~Understanding the Standard~~ Overview The focus of this standard is the mechanical wave-like nature of sound and some examples of its application. Sound is introduced in science standard 5.2, and it is expected that standard PS.8 will build upon and expand the concepts of the earlier standard. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (PS.1) in the context of the key concepts presented in this standard.

Standard PS.8

PS.8	The student will investigate and understand the characteristics of sound waves. Key concepts include a) wavelength, frequency, speed, amplitude, rarefaction, and compression; b) resonance; c) the nature of compression waves; and d) technological applications of sound.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The critical scientific concepts developed in this standard include the following: • Sound is produced by vibrations and is a type of mechanical energy. Sound travels in compression waves and at a speed much slower than light. It needs a medium (solid, liquid, or gas) in which to travel. In a compression wave, matter vibrates in the same direction in which the wave travels. • All waves exhibit certain characteristics: wavelength, frequency, and amplitude. As wavelength increases, frequency decreases. • The speed of sound depends on two things: the medium through which the waves travel and the temperature of the medium. • Resonance is the tendency of a system to vibrate at maximum amplitude at certain frequencies. • A compression (longitudinal) wave consists of a repeating pattern of compressions and rarefactions. Wavelength is measured as the distance from one compression to the next compression or the distance from one rarefaction to the next rarefaction. • Reflection and interference patterns are used in ultrasonic technology, including sonar and medical diagnosis.	In order to meet this standard, it is expected that students ~~should be able to~~ will • determine the relationship between frequency and wavelength. • analyze factors that determine the speed of sound through various materials and interpret graphs and charts that display this information. • identify examples illustrating resonance (e.g., musical instruments, Tacoma Narrows Bridge, ~~wine glasses~~ crystal stemware). • model a compression (longitudinal) wave and diagram, label, and describe the basic components: wavelength, compression, rarefaction, and frequency. • describe technological applications of sound waves and generally how each application functions. • design an investigation from a testable question related to sound. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis. ~~(Students should be able to use the inquiry skills represented in PS.1 and LS.1 to compose a clear hypothesis, create an organized data table, identify variables and constants, record data correctly, construct appropriate graphs, analyze data, and draw reasonable conclusions.)~~

Standard PS.9

PS.9	The student will investigate and understand the characteristics of transverse waves. Key concepts include a) wavelength, frequency, speed, amplitude, crest, and trough; b) the wave behavior of light; c) images formed by lenses and mirrors; d) the electromagnetic spectrum; and e) technological applications of light.
	~~Understanding the Standard~~ Overview This standard focuses on the nature of light and its applications. It builds upon standard 5.3, in which students investigate the characteristics of visible light. Standard PS.9 introduces students to the wave behavior of light. The speed of light in a vacuum is a constant. Light can change speed and direction as a result of moving from one medium to another. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (PS.1) in the context of the key concepts presented in this standard.

Standard PS.9

PS.9 The student will investigate and understand the characteristics of transverse waves. Key concepts include

a) wavelength, frequency, speed, amplitude, crest, and trough;
b) the wave behavior of light;
c) images formed by lenses and mirrors;
d) the electromagnetic spectrum; and
e) technological applications of light.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The critical scientific concepts developed in this standard include the following: • Visible light is a form of radiant energy that moves in transverse waves. • All transverse waves exhibit certain characteristics: wavelength, crest, trough, frequency, and amplitude. As wavelength increases, frequency decreases. There is an inverse relationship between frequency and wavelength. • ~~Light~~ Radiant energy travels in straight lines until it strikes an object where it can be reflected, absorbed, or transmitted. As visible light ~~waves~~ travels through different media, ~~they~~ it undergoes a change in speed that may result in refraction. • Electromagnetic waves are arranged on the electromagnetic spectrum by wavelength. All types of electromagnetic radiation travel at the speed of light, but differ in wavelength. The electromagnetic spectrum includes gamma rays, X-rays, ultraviolet, visible light, infrared, and radio and microwaves. • Radio waves are the lowest energy waves and have the longest wavelength and the lowest frequency. Gamma rays are the highest energy waves and have the shortest wavelength and the highest frequency. Visible light lies in between and makes up only a small portion of the electromagnetic spectrum. • Plane, concave, and convex mirrors all reflect light. Convex mirrors diverge light and produce a smaller, upright image. Concave mirrors converge light and produce an upright, magnified image if close and an inverted, smaller image if far away.	In order to meet this standard, it is expected that students ~~should be able~~ will • model a transverse wave and draw and label the basic components. Explain wavelength, amplitude, ~~and~~ frequency, crest, and trough. • describe the wave ~~theories~~ behavior of visible light (refraction, reflection, diffraction, and interference). • design an investigation to illustrate the behavior of visible light – reflection and refraction. Describe how reflection and refraction occur. • identify the images formed by lenses and mirrors. • compare the various types of electromagnetic waves in terms of wavelength, frequency, and energy. • describe an everyday application of each of the major forms of electromagnetic energy.

Standard PS.9

PS.9	The student will investigate and understand the characteristics of transverse waves. Key concepts include a) wavelength, frequency, speed, amplitude, crest, and trough; b) the wave behavior of light; c) images formed by lenses and mirrors; d) the electromagnetic spectrum; and e) technological applications of light.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
• Concave and convex lenses refract light. Concave lenses converge light. Convex lenses diverge light. • Diffraction is when light waves strike an obstacle and new waves are produced. • Interference takes place when two or more waves overlap and combine as a result of diffraction.	

Standard PS.10

PS.10	The student will investigate and understand the scientific principles of work, force, and motion. Key concepts include a) speed, velocity, and acceleration; b) Newton's laws of motion; c) work, force, mechanical advantage, efficiency, and power; and d) technological applications of work, force, and motion.
	~~Understanding the Standard~~ Overview PS.10 builds upon the concepts of simple machines, force, and work introduced in science standards 3.2 and 4.2. Standard PS.10 reviews and expands these basic ideas and introduces students to more mathematical concepts of motion. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (PS.1) in the context of the key concepts presented in this standard.

Standard PS.10

PS.10 The student will investigate and understand the scientific principles of work, force, and motion. Key concepts include

a) speed, velocity, and acceleration;
b) Newton's laws of motion;
c) work, force, mechanical advantage, efficiency, and power; and
d) technological applications of work, force, and motion.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The critical scientific concepts developed in this standard include the following: • Acceleration is the change in velocity per unit of time. An object moving with constant velocity has no acceleration. A decrease in velocity is negative acceleration or deceleration. A distance-time graph for acceleration is always a curve. Objects moving with circular motion are constantly accelerating because direction (and hence velocity) is constantly changing. • Newton's three laws of motion describe the motion of all common objects. • Mass and weight are not equivalent. Mass is the amount of matter in a given substance. Weight is a measure of the force due to gravity acting on a mass. Weight is measured in newtons. • A force is a push or pull. Force is measured in newtons. Force can cause objects to move, stop moving, change speed, or change direction. Speed is the change in position of an object per unit of time. Velocity may have a positive or a negative value depending on the direction of the change in position, whereas speed always has a positive value and is nondirectional. • Work is done when an object is moved through a distance in the direction of the applied force. • A simple machine is a device that makes work easier. Simple machines have different purposes: to change the effort needed (mechanical advantage), to change the direction or distance through which the force is applied, to change the speed at which the resistance moves, or a combination of these. Due to friction, the work put into a machine is always greater than the work output. The ratio of work output to work	In order to meet this standard, it is expected that students ~~should be able to~~ will • make measurements to calculate the speed of a moving object. • apply the concepts of speed, velocity, and acceleration when describing motion. • differentiate between mass and weight. • identify situations that illustrate each Law of Motion. • explain how force, mass, and acceleration are related. • apply the concept of mechanical advantage to test and explain how a machine makes work easier. • make measurements to calculate the work done on an object. • make measurements to calculate the power of an object. • solve basic problems given the following formulas: Speed = distance/time ($s = d/t$) Force = mass × acceleration ($F = ma$) Work = force × distance ($W = Fd$) Power = work/time ($P = W/t$). • explain how the concepts of work, force, and motion apply to ~~car safety technology, machines, and rockets~~ everyday uses and current technologies.

Standard PS.10

PS.10	The student will investigate and understand the scientific principles of work, force, and motion. Key concepts include a) speed, velocity, and acceleration; b) Newton's laws of motion; c) work, force, mechanical advantage, efficiency, and power; and d) technological applications of work, force, and motion.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
input is called efficiency. • Mathematical formulas are used to calculate speed, force, work, and power.	

Standard PS.11

PS.11	The student will investigate and understand basic principles of electricity and magnetism. Key concepts include a) static electricity, current electricity, and circuits; b) relationship between a magnetic field and an electric current; c) electromagnets, motors, and generators and their uses; and d) conductors, semiconductors, and insulators.
	~~Understanding the Standard~~ Overview Science standards 4.3 provide students with a strong foundation in the characteristics of electricity and simple circuits. Students in fourth grade construct series and parallel circuits and make electromagnets. Standard PS.11 is intended to provide a more in-depth and mathematical focus on circuits, current, static electricity, and the relationship between electricity and magnetism. It is intended that students will actively develop scientific investigation, reasoning, and logic skills, and the nature of science (PS.1) in the context of the key concepts presented in this standard.

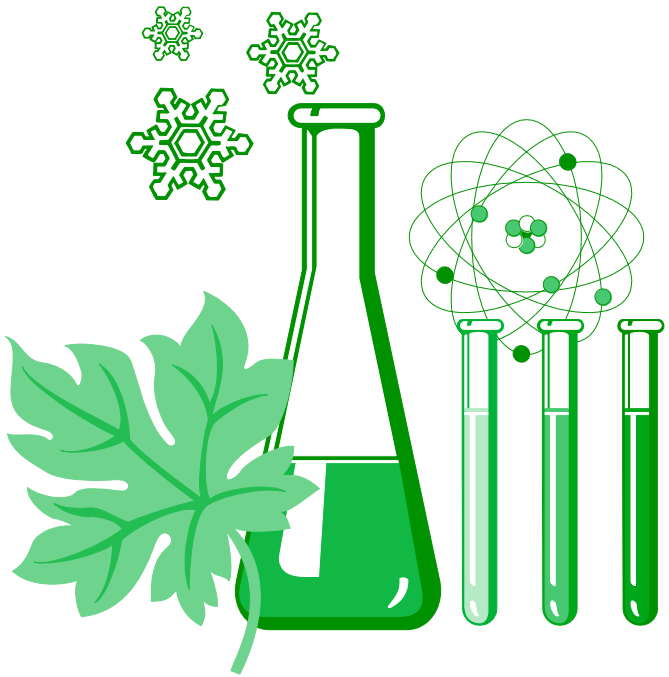
Standard PS.11

PS.11	The student will investigate and understand basic principles of electricity and magnetism. Key concepts include a) static electricity, current electricity, and circuits; b) relationship between a magnetic field and an electric current; c) electromagnets, motors, and generators and their uses.; and d) conductors, semiconductors, and insulators.

~~Overview~~ Essential Understandings	Essential Knowledge, Skills, and Processes
The critical scientific concepts developed in this standard include the following: • Several factors affect how much electricity can flow through a system. Resistance is a property of matter that affects the flow of electricity. Some substances have more resistance than others. • Friction can cause electrons to be transferred from one object to another. These static electrical charges can build up on an object and be discharged slowly or rapidly. This is often called static electricity. • Electricity is related to magnetism. Magnetic fields can produce electrical current in conductors. Electricity can produce a magnetic field and cause iron and steel objects to act like magnets. • Electromagnets are temporary magnets that lose their magnetism when the electric current is removed. Both a motor and a generator have magnets (or electromagnets) and a coil of wire that creates another magnetic field. • A generator is a device that converts mechanical energy into electrical energy. Most of the electrical energy we use comes from generators. Electric motors convert electrical energy into mechanical energy that is used to do work. Examples of motors include those in many household appliances, such as blenders and washing machines. • A conductor is a material that transfers an electric current well. An insulator is material that does not transfer an electric current. A semiconductor is in-between a conductor and an insulator. • The diode is a semiconductor device that acts like a one way valve to control the flow of electricity in electrical circuits. Solar cells are made of semiconductor diodes that produce direct current (DC) when visible	In order to meet this standard, it is expected that students ~~should be able to~~ will • design an investigation to illustrate the effects of static electricity. • construct and compare series and parallel circuits. • create an electromagnet and explain how it works. • explain the relationship between a magnetic field and an electric current. • construct simple circuits to determine the relationship between voltage, resistance, and current. • compare and contrast generators and motors and how they function. • identify situations in everyday life in which motors and generators are used. • provide examples of materials that are good conductors, semiconductors, and insulators. • ~~explain how diodes and transistors work.~~ • identify current applications of semiconductors and their uses (e.g., diodes and transistors).

Standard PS.11

PS.11	The student will investigate and understand basic principles of electricity and magnetism. Key concepts include a) static electricity, current electricity, and circuits; b) relationship between a magnetic field and an electric current; c) electromagnets, motors, and generators and their uses.; and d) conductors, semiconductors, and insulators.
~~Overview~~ Essential Understandings	**Essential Knowledge, Skills, and Processes**
light, infrared light (IR), or ultraviolet (UV) energy strikes them. Light emitting diodes (LED) emit visible light or infrared radiation when current passes through them. An example is the transmitter in an infrared TV remote or the lighting course behind the screen in an LED TV or notebook computer screen. • Transistors are semiconductor devices made from silicon, and other semiconductors. They are used to amplify electrical signals (in stereos, radios, etc.) or to act like a light switch turning the flow of electricity on and off.	



Science Standards of Learning Curriculum Framework

Earth Science

Final Review
November 18, 2010

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Board of Education
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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the Science Standards of Learning Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Standard ES.1

ES.1 The student will plan and conduct investigations in which

a) volume, area, mass, elapsed time, direction, temperature, pressure, distance, density, and changes in elevation/depth are calculated utilizing the most appropriate tools;
b) technologies, including computers, probeware, and geospatial technologies, are used to collect, analyze, and report data and to demonstrate concepts and simulate experimental conditions;
c) scales, diagrams, charts, graphs, tables, imagery, models, and profiles are constructed and interpreted;
d) maps and globes are read and interpreted, including location by latitude and longitude;
e) variables are manipulated with repeated trials; and
f) current applications are used to reinforce Earth science concepts.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Density expresses the relationship between mass and volume. • Information and data collected can be organized and expressed in the form of charts, graphs, and diagrams. • Scale relates to actual distance. • Topographic maps and satellite imagery are two-dimensional models that provide information defining three-dimensional landforms. They contain extensive information related to geographic as well as human structures and changes to the land surface, and are useful in understanding geologic processes. • Grid systems of latitude and longitude are used to define locations and directions on maps, globes, and charts.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • measure mass and volume of regular and irregular shaped objects and materials using common laboratory tools, including metric scales and graduated cylinders. • apply the concept of mass per unit volume and calculate density without being given a formula. • record data in systematic, properly-labeled, multicell tables, and using data, construct and interpret continuous line graphs, frequency distributions, bar graphs, and other explicating graphics that present a range of parameters, relationships, and pathways. • interpret data from a graph or table that shows changes in temperature or pressure with depth or altitude. • interpret landforms, water features, map scale, horizontal distance between points, elevation and elevation changes, latitude and longitude, human-made structures and other pertinent features on 7.5 minute quadrangles on topographic maps. • construct profiles from topographic contours. • ~~compare topographic maps of different scales.~~ • use latitude and longitude down to minutes, with correct north-south and east-west designations, to locate points on a map. • ~~construct a graph, table, chart, and/or diagram from data.~~

Standard ES.1

ES.1	The student will plan and conduct investigations in which a) volume, area, mass, elapsed time, direction, temperature, pressure, distance, density, and changes in elevation/depth are calculated utilizing the most appropriate tools; b) technologies, including computers, probeware, and geospatial technologies, are used to collect, analyze, and report data and to demonstrate concepts and simulate experimental conditions; c) scales, diagrams, charts, graphs, tables, imagery, models, and profiles are constructed and interpreted; d) maps and globes are read and interpreted, including location by latitude and longitude; e) variables are manipulated with repeated trials; and f) current applications are used to reinforce Earth science concepts.

Essential Understandings	Essential Knowledge and Skills
	• ~~interpret graphs and diagrams.~~ • ~~use scientific methodology to design and test a hypothesis.~~ • ~~locate points and directions on maps and globes, using latitude and longitude.~~ • ~~determine distance and elevation on a map.~~ • ~~identify a hilltop, stream, and valley on a topographic map.~~

Standard ES.2

ES.2 The student will demonstrate an understanding of the nature of science and scientific reasoning and logic. Key concepts include

a) science explains and predicts the interactions and dynamics of complex Earth systems;
b) evidence is required to evaluate hypotheses and explanations;
c) observation and logic are essential for reaching a conclusion; and
d) evidence is evaluated for scientific theories.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the concepts a) the natural world is understandable; b) science is based on evidence - both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. • Earth is a dynamic system, and all atmospheric, ~~geological~~ lithospheric, and ~~oceanographic~~ hydrospheric processes interrelate and influence one another. • A hypothesis is a tentative explanation that accounts for a set of facts and can be tested by further investigation. ~~Any valid hypothesis can be tested.~~ Only hypotheses that are testable are valid. A hypothesis can be supported, modified, or rejected based on collected data. Experiments are designed to test hypotheses. • Scientific theories are systematic sets of concepts that offer explanations for observed patterns in nature. Theories provide frameworks for relating data and guiding future research. Theories may change as new data become available. Any valid scientific theory has passed tests designed to invalidate it.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • analyze how natural processes explain multiple aspects of Earth systems and their interactions (e.g., storms, earthquakes, volcanic eruptions, floods, climate, mountain chains and landforms, geological formations and stratigraphy, fossils) can be used to make predictions of future interactions and allow scientific explanations for what has happened in the past. • make predictions, using scientific data and data analysis. • use data to support or reject a hypothesis. • differentiate between systematically-obtained, verifiable data and unfounded claims. • evaluate statements to determine if systematic science is used correctly, consistently, thoroughly, and in the proper context. • distinguish between examples of observations and inferences. • explain how ~~the scientific method~~ scientific methodology is used to ~~validate~~ support, refute, or improve scientific theories. • contrast the formal, scientific use of the term "theory" with the everyday nontechnical usage of "theory." • compare and contrast hypotheses, theories, and scientific laws. For example, students should be able to compare/contrast the Law of Superposition and the Theory of Plate Tectonics.

Standard ES.2

ES.2	The student will demonstrate an understanding of the nature of science and scientific reasoning and logic. Key concepts include a) science explains and predicts the interactions and dynamics of complex Earth systems; b) evidence is required to evaluate hypotheses and explanations; c) observation and logic are essential for reaching a conclusion; and d) evidence is evaluated for scientific theories.

Essential Understandings	Essential Knowledge and Skills
• There can be more than one scientific explanation for ~~any~~ phenomena. However, with competing explanations, generally one idea will eventually supersede the other as new tools, new observations, and verified data become available. • Changing relevant variables will generally change the outcome. • Scientific laws are generalizations of observational data that describe patterns and relationships. Laws may change as new data become available.	

Standard ES.3

ES.3 The student will investigate and understand the characteristics of Earth and the solar system. Key concepts include

a) position of Earth in the solar system;
b) sun-Earth-moon relationships (seasons, tides, and eclipses);
c) characteristics of the sun, planets and their moons, comets, meteors, and asteroids; and
d) the history and contributions of space exploration.

Essential Understandings

The concepts developed in this standard include the following:

- ~~Earth is one of nine planets in the solar system~~.
- The solar system consists of many types of celestial bodies. Earth is the third planet from the sun and is located between the sun and the asteroid belt. It has one natural satellite, the moon. Water occurs on Earth as a solid (ice), a liquid, or a gas (water vapor) due to Earth's position in the solar system.
- Earth revolves around the sun, tilted on its axis~~,~~. The axial tilt is responsible for the incidence and duration of sunlight striking a given hemisphere, that varies during the Earth's revolution around the Sun, thus causing seasons. ~~(e~~Equinoxes and solstices~~)~~ represent four distinct quarterly points signaling the cyclic change of seasons.
- The moon revolves around Earth creating the moon phases and eclipses. Solar eclipses occur when the moon blocks sunlight from Earth's surface, while lunar eclipses occur when Earth blocks sunlight from reaching the moon's surface.
- The tides are the ~~daily,~~ periodic rise and fall of water level caused by the gravitational pull of the sun and moon.
- The sun consists largely of hydrogen gas. Its energy comes from nuclear fusion of hydrogen to helium.
- There are essentially two types of planets in our solar system. The four inner (terrestrial) planets consist mostly of solid rock. Four of the outer planets are gas giants, consisting of thick outer layers of gaseous materials, perhaps with small rocky cores.
- The ~~fifth outer~~ dwarf planet, Pluto, has an unknown composition but

Essential Knowledge and Skills

~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will

- ~~Draw a diagram of the solar system, and label the planets~~
- analyze the role of 1) the position of Earth in the Solar System; 2) the size of Earth and sun; and 3) Earth's axial tilt in affecting the evolution of the planet and life on the planet.
- analyze historical explanations for the origin of the moon.
- create a model showing the position of Earth, the moon, and the resulting moon phases.
- explain why there is not a solar and lunar eclipse each month.
- create a model showing the position of Earth, moon, and sun during a solar and lunar eclipse.
- differentiate between the inner (terrestrial) planets and the outer (gaseous) planets and their corresponding atmospheric characteristics.
- compare and contrast the internal makeup of the four inner planets and explain why they vary so significantly.
- compare and contrast the atmospheres, planetary makeup, surface conditions, and rotation of the planets.
- compare the classification of the dwarf planet Pluto to the planets in relation to its orbit, and its similarity to other objects in the Kuiper Belt.
- compare and contrast the defining characteristics among moons, comets, meteoroids, and asteroids.

Standard ES.3

ES.3 The student will investigate and understand the characteristics of Earth and the solar system. Key concepts include

a) position of Earth in the solar system;
b) sun-Earth-moon relationships (seasons, tides, and eclipses);
c) characteristics of the sun, planets and their moons, comets, meteors, and asteroids; and
d) the history and contributions of space exploration.

Essential Understandings	Essential Knowledge and Skills
appears to be solid. It is part of the Kuiper Belt. • Moons are natural satellites of planets ~~that~~ and vary widely in composition. • Comets orbit the sun and consist mostly of frozen gases. • ~~Asteroids are rocky or metallic iron objects ranging in size from millimeters to kilometers. They are the source of most meteorites~~. • A meteoroid is debris located outside Earth's atmosphere; a meteor is debris located within Earth's atmosphere; and a meteorite is debris that has broken apart into smaller pieces before reaching Earth's surface. • Asteroids are usually leftover debris of the formation of the solar system, or creations of the collisions of other asteroids. • ~~Apollo 11 was the first manned landing on the moon.~~ • ~~The Hubble Space Telescope has greatly improved our understanding of the universe.~~ • The atmosphere of Venus is mostly carbon dioxide and very dense. The atmosphere of Mars is very thin and mostly carbon dioxide. • Much of our knowledge about the solar system is a result of space exploration efforts. These efforts continue to improve our understanding of the solar system.	• compare and contrast the characteristics of Venus, Earth, Mercury, and Mars, and interpret various reasons why each planet has such characteristics. • predict what conditions we would need to have in place for another celestial object to support life. • compare the various types of evidence obtained from the Apollo moon landings and other lunar exploration and how this is used to inform thinking about the moon. • ~~analyze the role of telescopes from Galileo's telescope to the Hubble telescope and evaluate these scientific tools as instruments of social and scientific change and enlightenment.~~ • analyze how the role of technology (Galileo's telescope, Hubble telescope, planetary orbiters, landers/rovers) has contributed to social and scientific change and enlightenment. • create a timeline of key events in space exploration.

Standard ES.4

ES.4	The student will investigate and understand how to identify major rock-forming and ore minerals based on physical and chemical properties. Key concepts include a) hardness, color and streak, luster, cleavage, fracture, and unique properties; and b) uses of minerals.

Essential Understandings	Essential Knowledge and Skills
• There is a difference between rocks and minerals. Most rocks are made of one or more minerals. • A mineral is a naturally occurring, inorganic, solid substance with a definite chemical composition and structure~~. Minerals~~ and can be identified based on specific chemical and physical properties. • The major elements found in Earth's crust are oxygen, silicon, aluminum, and iron. The most abundant group of minerals is the silicates, which contain silicon and oxygen. Some common silicates include feldspar and quartz. • The carbonate group of minerals is composed of the carbonate compound CO_3. Some common carbonates are calcite and dolomite. • The oxide group of minerals is composed of oxygen and a metal. Some common oxides include hematite and magnetite. • Minerals are important to human wealth and welfare.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • analyze why certain common metallic elements (iron, aluminum, silicon) are rarely, if ever, found in the native state. • analyze the distribution and persistence of minerals at or near Earth's surface in terms of Earth's general structure, plate tectonics, and chemical and physical weathering. • ~~recognize in hand sample common members of the silicate groups and carbonate rock forming minerals.~~ • analyze the relationship between the qualities of cleavage, fracture, and hardness and the molecular structure and chemistry of silicates, ~~and other common minerals~~ carbonates, and oxides. • ~~recognize accessory minerals often found in common rocks.~~ • identify minerals ~~may be identified~~ by their physical properties, such as hardness, color, luster, and streak. • recognize some major rock-forming minerals ~~are~~ such as quartz, feldspar, calcite, and mica. • recognize ore minerals includ~~e~~ing pyrite, magnetite, hematite, galena, graphite, and sulfur.

Standard ES.5

ES.5	The student will investigate and understand the rock cycle as it relates to the origin and transformation of rock types and how to identify common rock types based on mineral composition and textures. Key concepts include a) igneous rocks; b) sedimentary rocks; and c) metamorphic rocks.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Rocks can be identified on the basis of mineral content and texture. • The processes by which rocks are formed define the three major groups of rocks. • The rock cycle is the process by which all rocks are formed and how basic Earth materials are recycled through time. • Igneous rock forms from molten rock that cools and hardens either below or on Earth's surface. Extrusive igneous rocks have small or no crystals, resulting in fine-grained or glassy textures~~ Extrusive igneous rocks~~ and include pumice, obsidian, and basalt. Intrusive igneous rocks have larger crystals and a coarser texture ~~Intrusive igneous rocks~~ and include granite. • Sedimentary rocks may be formed either by rock fragments or organic matter being bound together or by chemical precipitation. ~~Sedimentary rocks are clastic or chemical.~~ Clastic sedimentary rocks are made up of fragments of other rocks and include sandstone, conglomerate, and shale. Non-clastic sedimentary rocks include limestone and rock salt. • Metamorphic rocks form when any rock is changed by the effects of heat, pressure, or chemical action.~~ Metamorphic rocks can be foliated or unfoliated (non-foliated).~~ Foliated metamorphic rocks have bands of different minerals and include ~~S~~slate, schist, and gneiss ~~are foliated metamorphic rocks~~. Unfoliated metamorphic rocks have little or no banding and are relatively homogenous throughout and include ~~M~~marble and quartzite ~~are unfoliated metamorphic rocks~~.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • comprehend and identify various igneous rock textural features and mineral components with a hand sample or by description, and analyze the significance of these features in terms of mode of origin and history. • analyze and identify various sedimentary rocks in terms of mode of origin and history, using sedimentary features (grain size, texture, and composition). • analyze the major groups of metamorphic rocks for mineral composition and textural features and determine the potential parent rock and in terms of the rock cycle. • analyze a sequence of rocks in terms of types, textures, composition, fossils, structural, and weathering features in order to infer the history of the sequence over time. • integrate the rock cycle with Plate Tectonics Theory and determine how this is reflected in the geology of Virginia's five physiographic provinces. • ~~interpret the rock cycle diagram.~~ • classify the following rock types as igneous, metamorphic, or sedimentary: pumice, obsidian, basalt, granite, sandstone, conglomerate, shale, limestone, slate, schist, gneiss, marble, and quartzite. • differentiate between clastic and non-clastic sedimentary rocks. • compare and contrast distinguishing characteristics of the crystal

Standard ES.5

ES.5	The student will investigate and understand the rock cycle as it relates to the origin and transformation of rock types and how to identify common rock types based on mineral composition and textures. Key concepts include a) igneous rocks; b) sedimentary rocks; and c) metamorphic rocks.

Essential Understandings	Essential Knowledge and Skills
	structure and textures of extrusive and intrusive igneous rocks. • describe the structure of foliated and unfoliated metamorphic rocks.

Standard ES.6

ES.6 The student will investigate and understand the differences between renewable and nonrenewable resources. Key concepts include

a) fossil fuels, minerals, rocks, water, and vegetation;
b) advantages and disadvantages of various energy sources;
c) resources found in Virginia; and
d) environmental costs and benefits.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Resources are limited and are either renewable or nonrenewable. • There are advantages and disadvantages to using any energy source. • Virginia has many natural resources. • Modern living standards are supported by extensive use of both renewable and nonrenewable resources. • Extraction and use of any resource carries an environmental cost that must be weighed against economic benefit. • Renewable resources can be replaced by nature at a rate close to the rate at which they are used. Renewable resources include vegetation, sunlight, and surface water. • Nonrenewable resources are ~~renewed~~ replenished very slowly or not at all. Nonrenewable resources include coal, oil, and minerals. • Fossil fuels are nonrenewable and may cause pollution, but they are relatively cheap and easy to use once they are extracted. • In Virginia, major rock and mineral resources include coal for energy, gravel and crushed stone for road construction, silica for electronics, zirconium and titanium for advanced metallurgy, and limestone for making concrete. • Clean water resources, while renewable, are directly impacted by human activity through extraction and pollution.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • analyze the formation of fossil fuels in terms of the rock cycle and Plate Tectonics Theory, and relate the formation of fossil fuels to ancient biologic and atmospheric conditions and changes and locations within Virginia. • analyze how Virginia's production and use of various natural resources has changed over time. Define and cite differences over time especially in the last 150 years. • evaluate Virginia's potential as a producer of renewable energy sources. • assess the role of fossil fuels and renewable energy sources in the future and compare and contrast the environmental benefits and costs among the various options. • analyze the advantages and disadvantages of various energy sources. • analyze a range of emerging energy and mineral resources in Virginia in terms of costs and benefits. • determine the sources of clean water in their community and analyze consumption and supply data.

Standard ES.7

ES.7 The student will investigate and understand geologic processes including plate tectonics. Key concepts include
a) geologic processes and their resulting features; and
b) tectonic processes.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Virginia has a billion-year-long tectonic and geologic history. • Virginia has five physiographic provinces produced by past episodes of tectonic activity and continuous geologic activity. • Each province has unique physical characteristics resulting from its geologic past. • Geologic processes produce characteristic structures and features. • The five physiographic provinces of Virginia are Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau. • The Coastal Plain is a flat area ~~underlain by~~ composed of young, unconsolidated sediments underlain by older crystalline basement rocks. These layers of sediment were produced by erosion of the Appalachian Mountains and Piedmont and then deposited on the Coastal Plain when sea levels were higher in the past. • The Piedmont is an area of rolling hills underlain by mostly ancient igneous and metamorphic rocks. The igneous rocks are the roots of volcanoes formed during an ancient episode of subduction that occurred before the formation of the Appalachian Mountains. • The Blue Ridge is a high ridge separating the Piedmont from the Valley and Ridge Province. The billion-year-old igneous and metamorphic rocks of the Blue Ridge are the oldest in the state. ~~Some metamorphism of these rocks occurred during the formation of the Appalachian Mountains.~~ • The Valley and Ridge province is an area with long parallel ridges and valleys underlain by ancient folded and faulted sedimentary rocks. The folding and faulting of the sedimentary rocks occurred during a collision between Africa and North America. The collision, which occurred in the	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • label on a map ~~and recognize the major features of~~ the physiographic provinces of Virginia. • comprehend the topographic, rock-type and geologic-structural characteristics of each physiographic province of Virginia. • analyze the geologic history of Virginia in terms of the structures, rock types, and topography represented in the five physiographic provinces. • integrate and interpret the rock cycle, plate tectonics, and Virginia's geology in an interacting diagram. • analyze how multiple continental collisions and rifting events over the last billion years have created the current physiography of Virginia. • comprehend and apply the details of Plate Tectonics Theory to the formation of continents, mountain chains, island arcs, deep open trenches, earthquake zones, and continental and mid-ocean volcanism. • analyze the composition and structure of the continental and oceanic lithosphere in terms of topographic features, density, thickness, and rates of motion. • compare and contrast various types of volcanism and geothermal activity (i.e., Hawaii, Iceland, Mount St. Helens, Catoctin Greenstone, Tambora, the Deccan Traps, and Yellowstone). • compare and contrast different types of current and ancient plate boundaries (i.e., Japan, California, New Madrid, Missouri, the Appalachian system, Iceland, and Tonga). • analyze how seismic waves provide evidence of the structure of the

Standard ES.7

ES.7 The student will investigate and understand geologic processes including plate tectonics. Key concepts include
a) geologic processes and their resulting features; and
b) tectonic processes.

Essential Understandings	Essential Knowledge and Skills
late Paleozoic era, produced the Appalachian Mountains. • The Appalachian Plateau has rugged, irregular topography and is underlain by ancient, flat-lying sedimentary rocks. The area is actually a series of plateaus separated by faults and erosional down-cut valleys. Most of Virginia's coal resources are found in the plateau province. • ~~The core, mantle, and crust of Earth are dynamic systems, constantly in motion.~~ • Earth consists of a solid, mostly iron inner core; a liquid, mostly iron outer core; a ~~rocky~~ crystalline but largely plastic mantle; and a rocky, brittle crust. • Earth's lithosphere is divided into plates that are in motion with respect to one another. The lithosphere is composed of the crust and upper portion of the mantle. There are two different types of ~~crust~~ lithospheres — oceanic and continental — that have very different physical and mineralogic characteristics. The ocean ~~crust~~ lithosphere is relatively thin, young, and dense. The continental ~~crust~~ lithosphere is relatively thick, old, and less dense. • Most large scale, high-energy events of geologic activity (e.g., earthquakes, volcanoes, and mountain building) occur~~s~~ as a result of relative motion along plate boundaries. • Plate motion occurs as a consequence of convection in Earth's mantle, including upwelling of material from the deep mantle in rift zones, the lateral movement of tectonic plates, and the sinking dense, old plates at subduction zones. ~~Plate tectonics is driven by convection in the mantle~~. • Weathering, erosion, and deposition are interrelated processes. Weathering is the process by which rocks are broken down chemically and physically by the action of water, air, and organisms. Erosion is the process by which Earth materials are ~~transported~~ physically incorporated by moving water, ice, or wind for transportation. Deposition is the process by which Earth materials carried by wind, water, or ice settle out	deep Earth including the inner and outer core in terms of composition, density, and viscosity. • analyze the body of evidence for Plate Tectonics Theory (i.e., seafloor age, magnetic information, seismic profiles, laser-measured motion studies, fossil evidence, rock types associated with particular tectonic environments). • analyze the various structures produced in convergent plate boundaries. • offer interpretations of the tectonic history of an area based on the range and type of rocks found in that area. • compare and contrast the tectonic activity of the east coast and the west coast of North America.

Standard ES.7

ES.7	The student will investigate and understand geologic processes including plate tectonics. Key concepts include a) geologic processes and their resulting features; and b) tectonic processes.
Essential Understandings	**Essential Knowledge and Skills**
and are ~~deposited~~ left in a location when energy levels decrease. The size of the material deposited is proportional to the available energy of the medium of transport. • Relative plate motions and plate boundaries are convergent (subduction and continental collision), divergent (seafloor spreading), or transform. Major features of convergent boundaries include collision zones (folded and thrust-faulted mountains) and subduction zones (volcanoes and trenches). Major features of divergent boundaries include mid-ocean ridges, rift valleys, ~~and~~ fissure volcanoes, and flood lavas. Major features of transform boundaries include strike-slip faults. • Earthquake activity of varying energy levels and depths is associated with all plate boundaries. • A volcano is an opening where magma erupts onto Earth's surface. Most volcanic activity is associated with subduction, rifting, or seafloor spreading. Hot spot volcanic activity, such as volcanic islands, is exceptional in that it is not related to plate boundaries but derived from a deep, localized heat source. • A fault is a break or crack in Earth's crust along which movement has occurred. • ~~Most active faults are located at or near plate boundaries. Earthquakes result when movement occurs along a fault.~~ • ~~When rocks are compressed horizontally, their layers may be deformed into wave-like forms called folds. This commonly occurs during continental collisions.~~ • Plate tectonic processes serve as the major driver of the rock cycle. Plate tectonics drive the evolution of Earth's surface features and materials by fractionating material by chemical, mineralogic, and physical properties. Continental drift is a consequence of plate tectonics.	

Standard ES.8

ES.8 The student will investigate and understand how freshwater resources are influenced by geologic processes and the activities of humans. Key concepts include

a) processes of soil development;
b) development of karst topography;
c) relationships between groundwater zones, including saturated and unsaturated zones, and the water table;
d) identification of sources of fresh water including rivers, springs, and aquifers, with reference to the hydrologic cycle;
e) dependence on freshwater resources and the effects of human usage on water quality; and
f) identification of the major watershed systems in Virginia, including the Chesapeake Bay and its tributaries.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Soil is formed from the weathering of rocks and organic activity~~. Soil~~ and is composed of loose rock fragments and clay derived from weathered rock mixed with organic material. • Karst topography is developed in areas underlain by carbonate rocks, including limestone and dolomite. Karst topography includes features like caves and sinkholes~~. Karst topography~~ and forms when limestone is slowly dissolved away by slightly acidic groundwater. Where limestone is abundant in the Valley and Ridge province of Virginia, karst topography is common. • Permeability is a measure of the ability of a rock or sediment to transmit water or other liquids. Water does not pass through impermeable materials. A substantial amount of water is stored in permeable soil and rock underground. • Earth's fresh water supply is finite. Geological processes, such as erosion, and human activities, such as waste disposal, can pollute water supplies. • Water is continuously being passed through the hydrologic cycle. Fresh water is necessary for survival and most human activities. • The three major regional watershed systems in Virginia lead to the Chesapeake Bay, the North Carolina sounds, and the Gulf of Mexico.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • interpret a simple groundwater diagram showing the zone of aeration, the zone of saturation, the water table, and an aquifer. • interpret a simple hydrologic cycle diagram, including evaporation, condensation, precipitation, and runoff. • locate the major Virginia watershed systems on a map (Chesapeake Bay, Gulf of Mexico, and North Carolina sounds). • analyze the formation of karst in terms of rock type, solubility and permeability, uplift, the water table, and chemical and physical weathering. • analyze the presence of groundwater in various types of rock terrains, including areas found in each of the physiographic provinces of Virginia. • analyze the relationship between salt-water intrusion in the ground water in certain areas of eastern Virginia and buried crater structures.

Standard ES.9

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 concepts include

a) traces and remains of ancient, often extinct, life are preserved by various means in many sedimentary rocks;
b) superposition, cross-cutting relationships, index fossils, and radioactive decay are methods of dating bodies of rock;
c) absolute 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.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The history of Earth and the ages of rocks can be investigated and understood by studying rocks and fossils. • Evidence of ancient, often extinct life is preserved in many sedimentary rocks. A fossil is the remains, impression, or other evidence preserved in rock of the former existence of life. Fossil evidence indicates that life forms have changed and become more complex over geologic time. Some ways in which fossils can be preserved are molds, casts, and original bone or shell. • ~~Nearly all fossils are found in sedimentary rocks.~~ • Relative time places events in a sequence without assigning any numerical ages. Fossils, superposition, and cross-cutting relations are used to determine the relative ages of rocks. Absolute time places a numerical age on an event. Radioactive decay is used to determine the absolute age of rocks. • ~~Earth is very ancient – about 4.6 billion years old.~~ The age of Earth is about 4.6 billion years. • In Virginia, fossils are found mainly in the Coastal Plain, Valley and Ridge, and Appalachian Plateau provinces. Most Virginia fossils are of marine organisms. This indicates that large areas of the state have been periodically covered by seawater. • Paleozoic, Mesozoic, and Cenozoic fossils are found in Virginia.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • describe how life has changed and become more complex over geologic time. • interpret a simple geologic history diagram, using superposition and cross-cutting relations. • analyze how radioactive decay provides a reliable method to determine the age of many types of organic and inorganic materials. • analyze the impact and role of global catastrophies (including asteroid/comet impacts, volcanism, continental collisions, climate collapse) on extinctions and evolution. • analyze and interpret complex cross sections using both relative and absolute dating to unravel and define the geologic history of the section.

Standard ES.10

ES.10 The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include

a) physical and chemical changes related to tides, waves, currents, sea level and ice cap variations, upwelling, and salinity variations;
b) importance of environmental and geologic implications;
c) systems interactions;
d) features of the seafloor as reflections of tectonic processes; and
e) economic and public policy issues concerning the oceans and the coastal zone including the Chesapeake Bay.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The ocean is a dynamic system in which many chemical, biological, and physical changes are taking place. The oceans are an important source of food and mineral resources as well as a venue for recreation and transportation. Sea level falls when glacial ice caps grow and rises when the ice caps melt. • Most waves on the ocean surface are generated by wind. • There are large current systems in the oceans that carry warm water towards the poles and cold water towards the equator. • Upwellings bring cold, nutrient-rich water from the deep ocean to the surface and are areas of rich biological activity. • The tides are the ~~daily,~~ periodic rise and fall of water level caused by the gravitational pull of the sun and moon. • The oceans' resources are finite and should be utilized with care. • Algae in the oceans are an important source of atmospheric oxygen. • The ocean is the single largest reservoir of heat at Earth's surface. The stored heat in the ocean drives much of Earth's weather~~. The stored heat in the ocean~~ and causes climate near the ocean to be milder than climate in the interior of continents. • Convection is the major mechanism of energy transfer in the oceans, atmosphere, and Earth's interior. • The topography of the seafloor is at least as variable as that on the continents. Features of the seafloor that are related to plate tectonic	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • identify the effects of human activities on the oceans. • analyze the potential impact of a major environmental disaster on the base of the food web and vertebrate organisms; economics; cultures; and future productivity. • analyze the relationship between moving continents, the presence of ice caps, and ocean circulation over long periods of time. • relate important ocean conditions, including El Niño, to weather on the continents. • evaluate the role of the marine environment in the extraction of carbon dioxide in carbonates and the production of oxygen. • analyze the role of ocean currents in the distribution of heat from the equatorial regions to the poles, and predict what changes may occur as continents move and atmospheric conditions and climate vary. • compare Atlantic Ocean and Gulf of Mexico water temperatures during the yearly cycle, and relate this to the formation of storms. • describe how different types of pollution can pollute the Chesapeake Bay even though the pollutant source may be hundreds of miles from the Bay.

Standard ES.10

ES.10	The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include a) physical and chemical changes related to tides, waves, currents, sea level and ice cap variations, upwelling, and salinity variations; b) importance of environmental and geologic implications; c) systems interactions; d) features of the seafloor as reflections of tectonic processes; and e) economic and public policy issues concerning the oceans and the coastal zone including the Chesapeake Bay.

Essential Understandings	Essential Knowledge and Skills
processes include mid-ocean ridges and trenches (continental margins, trenches, and mid ocean ridges). Other major topographic features of the oceans are continental shelves, continental slopes, abyssal plains, and seamounts. • The oceans are environmentally and economically important. Human activities and public policy have important consequences for the oceans. The impact of human activities, such as waste disposal, construction, and agriculture, affect the water quality within watershed systems and ultimately the ocean. Pollution and overfishing can harm or deplete valuable resources. • Estuaries, like the Chesapeake Bay, are areas where fresh and salt water mix, producing variations in salinity and high biological activity. Chemical pollution and sedimentation are great threats to the ~~chemical and biological~~ well-being of estuaries and oceans.	

Standard ES.11

ES.11	The student will investigate and understand the origin and evolution of the atmosphere and the interrelationship of geologic processes, biologic processes, and human activities on its composition and dynamics. Key concepts include a) scientific evidence for atmospheric composition changes over geologic time; b) current theories related to the effects of early life on the chemical makeup of the atmosphere; c) atmospheric regulation mechanisms including the effects of density differences and energy transfer; and d) potential changes to the atmosphere and climate due to human, biologic, and geologic activity.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The composition of Earth's atmosphere has changed over geologic time. Earth's atmosphere is unique in the solar system in that it contains substantial oxygen. • ~~The early atmosphere contained little oxygen and more carbon dioxide than the modern atmosphere.~~ The most primitive atmosphere was comprised of mainly helium and hydrogen. After the moon was formed, the early atmosphere contained mostly CO_2, CO and water vapor. This atmosphere was then modified by early photosynthetic life. • Early photosynthetic life such as cyanobacteria (blue-green algae) consumed carbon dioxide and generated oxygen. It was only after early photosynthetic life generated oxygen that animal life became possible. • Earth's atmosphere is 21 percent oxygen, 78 percent nitrogen, and 1 percent trace gases. The composition of the atmosphere can change due to human, biologic, and geologic activity. Human activities have increased the carbon dioxide content of the atmosphere. Man-made chemicals have decreased the ozone concentration in the upper atmosphere. Volcanic activity and meteorite impacts can inject large quantities of dust and gases into the atmosphere. • The ability of Earth's atmosphere to absorb and retain heat is affected by the presence of gases like water vapor and carbon dioxide.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • analyze the array of climate feedback mechanisms that control the Earth's temperature over time, and compare and contrast these feedback mechanisms to those operating on inner planets and the gas giants. • analyze the evidence for atmospheric compositional change over geologic time including oxygen and carbon sinks and the role of photosynthetic organisms. • explain how volcanic activity or meteor impacts could affect the atmosphere and life on Earth. • explain how biologic activity, including human activities, may influence global temperature and climate.

Standard ES.12

ES.12	The student will investigate and understand that energy transfer between the sun and Earth and its atmosphere drives weather and climate on Earth. Key concepts include a) observation and collection of weather data; b) prediction of weather patterns; c) severe weather occurrences, such as tornadoes, hurricanes, and major storms; and d) weather phenomena and the factors that affect climate including radiation, conduction, and convection.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Energy transfer between Earth's surface and the atmosphere creates the weather. • Weather and climate are different. Both weather and climate are measurable and, to a certain extent, predictable. Weather describes day-to-day changes in atmospheric conditions. Climate describes the typical weather patterns for a given location over a period of many years. Instrumentation is used to collect weather and climate data. • The four major factors affecting climate are latitude, elevation, proximity to bodies of water, and position relative to mountains. Earth's major climatic zones are the polar, temperate, and tropical zones. Areas near the equator receive more of the sun's energy per unit area than areas nearer the poles. • Earth's surface is much more efficiently heated by the sun than is the atmosphere. The amount of energy reaching any given point on Earth's surface is controlled by the angle of sunlight striking the surface and varies with the seasons. • Winds are created by uneven heat distribution at Earth's surface and modified by the rotation of Earth. The Coriolis effect causes deflections of the atmosphere due to the rotation of Earth. Global wind patterns result from the uneven heating of Earth by the sun and are influenced by the Coriolis effect. • Convection in the atmosphere is a major cause of weather. Convection is the major mechanism of energy transfer in the oceans, atmosphere, and Earth's interior.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • ~~label a diagram of global wind patterns.~~identify and describe the direction of local winds (land, sea breezes and jet stream). • read and interpret data from a thermometer, a barometer, and a psychrometer. • predict weather based on cloud type, temperature, and barometric pressure. • read and interpret a weather map containing fronts, isobars, and isotherms. • read and interpret weather station models. • identify types and origins of air masses, fronts and the accompanying weather conditions. • read and interpret climate graphs. • label a diagram of global climate zones and the surface movement of ocean currents. • label a diagram that demonstrates the interaction of Earth's atmosphere and energy transfer (conduction, convection, and radiation). • analyze the impact of satellite technology on weather prediction and the tracking of severe storms, including hurricanes, and evaluate the cost and benefits of this technology in terms of lives and property saved. Predict the impact on storm preparedness if there were no

Standard ES.12

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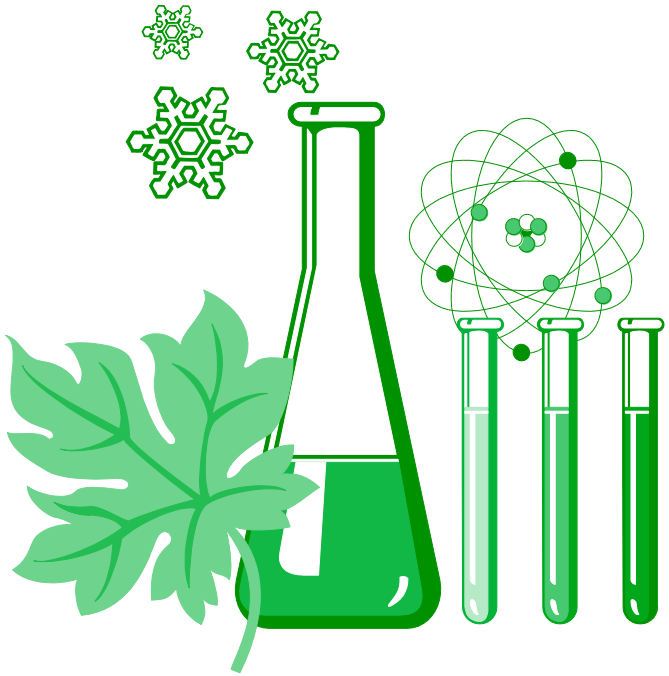
Essential Understandings	Essential Knowledge and Skills
• The conditions necessary for cloud formation are air at or below dew point and presence of condensation nuclei. Cloud droplets can join together to form precipitation. • A tornado is a narrow, violent funnel-shaped column of spiral winds that extends downward from the cloud base toward Earth. A hurricane is a tropical cyclone (counterclockwise movement of air) characterized by sustained winds of 120 kilometers per hour (75 miles per hour) or greater.	weather satellites.

Standard ES.13

ES.13 The student will investigate and understand scientific concepts related to the origin and evolution of the universe. Key concepts include
a) cosmology including the Big Bang theory; and
b) the origin and evolution of stars, star systems, and galaxies.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The universe is vast in size and very old. • The ~~b~~Big ~~b~~Bang theory is our best current model for the origin of the universe. The ~~b~~Big ~~b~~Bang theory states that the universe began in a very hot, dense state that expanded and eventually condensed into galaxies. • The solar nebular theory is our best current idea for the origin of the solar system. The solar nebular theory explains that the planets formed through the condensing of the solar nebula. • Stars have a finite lifetime and evolve over time. The mass of a star controls its evolution, ~~length of its lifetime~~ lifespan, and ultimate fate. Stars form by condensation and gravitational compression of interstellar gas and dust. • The Hertzsprung-Russell diagram illustrates the relationship between the absolute magnitude and the surface temperature of stars. As stars evolve, their position on the Hertzsprung-Russell diagram moves. • Galaxies are collections of billions of stars. The basic types of galaxies are spiral, elliptical, and irregular. • The solar system is located in the Milky Way galaxy. • A light-year is the distance light travels in one year and is the most commonly used measurement for distance in astronomy. • Much of our information about our galaxy and the universe comes from ground-based observations across the electromagnetic spectrum. Much information about other planets comes from ground-based observations from Earth, but also from landers and orbiting spacecraft.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • contrast the life span and energy output of a blue giant star to that of the sun and relate this to the potential existence of life on planets in its orbit. • explain the potential origin and role of ultra massive black holes in the center of galaxies. • using the Hertzsprung-Russell diagram, classify stars as to their place on the main sequence or in beginning or end points in their life cycles. • evaluate the probability of travel to nearby solar systems using current spacecraft speeds. • analyze the various fusion product~~ion~~s of a blue giant star over its lifetime, and relate this to the presence and abundance of elements that make up our solar system and its contents, including living organisms.



Science Standards of Learning Curriculum Framework

Biology

Final Review
November 18, 2010

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Board of Education
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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Standard BIO.1

BIO.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) observations of living organisms are recorded in the lab and in the field;
b) hypotheses are formulated based on direct observations and information from scientific literature;
c) variables are defined and investigations are designed to test hypotheses;
d) graphing and arithmetic calculations are used as tools in data analysis;
e) conclusions are formed based on recorded quantitative and qualitative data;
f) sources of error inherent in experimental design are identified and discussed;
g) validity of data is determined;
h) chemicals and equipment are used in a safe manner;
i) appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data, communicating results, modeling concepts, and simulating experimental conditions;
j) research utilizes scientific literature;
k) differentiation is made between a scientific hypothesis, theory, and law;
l) alternative scientific explanations and models are recognized and analyzed; and
m) current applications of biological concepts are used.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts a) the natural world is understandable; b) science is based on evidence - both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. • Active participation in scientific investigations is necessary to develop an understanding of biology as an experimental science. • The continual use and development of cognitive and manipulative skills associated with the formulation of ~~the~~ scientific explanations is	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • conduct investigations in the classroom and field, as appropriate, and critically examine investigations reported in scientific literature and databases. • collect preliminary observations, both qualitative and quantitative. • make clear distinctions among observations, inferences, and predictions. • formulate hypotheses based on cause-and-effect relationships. • justify hypotheses based on both preliminary observations and scientific literature. • identify the independent variable (IV) and the values of the IV that will be used in the experiment. • select dependent variables that allow collection of quantitative data. • identify variables that must be held constant.

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m) current applications of biological concepts are used.

Essential Understandings	Essential Knowledge and Skills
important. • The design of sound scientific experiments relies on systematic preliminary observations and data collected in the laboratory and in the field, as well as on a knowledge base gained from an examination of related scientific literature. Prior establishment of an adequate knowledge base is essential before hypotheses can be developed and tested. • ~~It is typical for scientists to disagree with one another about the interpretation of evidence or a theory being considered. This is partly a result of the unique background (social, educational, etc.) that individual scientists bring to their research.~~ • Because of ~~this inherent subjectivity, scientific inquiry~~ the rigor that scientific inquiry requires, science is a process that involves evaluating the results and conclusions proposed by other scientists. • Scientific tools including microscopes, computers, graphing calculators, and probeware allow for the gathering and analysis of data. • The analysis of evidence and data is essential in order to make sense of the content of science.	• establish controls as appropriate. • write clear, replicable procedures. • ~~Use appropriate technology for data collection, including probeware interfaced to a graphing calculator and/or computer, microscope, video microscope, or digital camera with image processing software.~~ identify and use appropriate technology for data collection and analysis, including probeware (i.e., sensors for temperature, pH and dissolved oxygen). • record quantitative data in clearly labeled tables with units. • include labeled diagrams in the data record. • determine the range, mean, and values for data, using a graphing calculator and/or computer spreadsheet software. • plot data graphically, showing independent and dependent variables. • describe ~~linear mathematical functions~~ trends from the data where appropriate, using a graphing calculator and/or computer spreadsheet.

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i) appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data, communicating results, modeling concepts, and simulating experimental conditions;
j) research utilizes scientific literature;
k) differentiation is made between a scientific hypothesis, theory, and law;
l) alternative scientific explanations and models are recognized and analyzed; and
m) current applications of biological concepts are used.

Essential Understandings	Essential Knowledge and Skills
• Multiple data manipulation and analysis strategies are available to help explain results of quantitative investigations. • Data and evidence should come from a variety of sources, including student investigation, peer investigation, and databases. • The scientific establishment sometimes rejects new ideas, and new discoveries often spring from unexpected findings. • Scientific knowledge usually grows slowly through contributions from many different investigators from diverse cultures. • Science depends on experimental and observational confirmation and is subject to change as new evidence becomes available. • A hypothesis can be supported, modified, or rejected based on collected data. A hypothesis is a tentative explanation that accounts for a set of facts and that can be tested by further investigation. A theory is an accepted explanation of a large body of information, experimental and inferential, and serves as an overarching framework for numerous concepts. It is subject to change as new evidence becomes available. A law is a statement of fact meant to describe, in concise terms, an action.	• recognize and discuss contradictory or unusual data. • determine the extent to which data support~~s~~/do~~es~~ not support a hypothesis, and propose further hypotheses and directions for continued research. • discuss the validity of results as related to accuracy, confidence, and sources of experimental error based on number of trials and variance in the data. • use evidence, apply logic, and construct an argument for conclusions based on reported data. • ~~explain how competing scientific theories based on the same observations can be equally valid.~~ • recognize that in order to ensure the validity of scientific investigations, ~~other members of the scientific community~~ they must be evaluated by other members of the scientific community. • compare and contrast hypotheses, theories and laws. • identify and describe scientific theories that have been changed or

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Essential Understandings	Essential Knowledge and Skills
It is generally accepted to be true and universal.	modified over time.

Standard BIO.2

BIO.2 The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include

a) water chemistry and its impact on life processes;
b) the structure and function of macromolecules;
c) the nature of enzymes; and
d) the capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Water is essential for life on Earth. Water absorbs heat when it evaporates, allowing organisms to release excess heat. The solid form of water, ice, floats, preventing lakes and oceans from freezing solid. Water molecules are both cohesive and adhesive due to the nature of hydrogen bonding ~~(polar covalent and hydrogen bonding)~~. • About two-thirds of the mass of a cell is made up of water, and most of the biochemical processes of life occur in water solutions. Water is able to dissolve many substances (due to polarity); therefore, the water inside and outside of cells is able to carry nutrients into and around cells and wastes away from cells. • ~~Water is able to absorb large amounts of heat. As a result, lakes and oceans stabilize air and land temperatures.~~ • ~~The pH scale ranges from 0 to 14. The pH of pure water is 7. Substances added to water can lower or raise the pH. A solution with a pH below 7 is acidic. A solution with a pH above 7 is basic.~~ • The pH scale ranges from 0 to 14. The pH of pure water is 7. Substances added to water can lower or raise the pH. A solution with a pH below 7 is acidic. A solution with a pH above 7 is basic. • Organisms can tolerate only small changes in pH because every cell has a particular pH at which it functions best. For example, changes in pH cause changes in enzyme conformation, resulting in a change in activity. Most cells function best within a narrow range of temperature and pH. At very low temperatures, reaction rates are too slow. High temperatures or extremes of pH can irreversibly change the structure of proteins and alter their function.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • explain the importance of the chemical and physical properties of water that make it vital to life. • recognize that ~~T~~the main components of a living cell are carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. Carbon atoms can easily bond to several other carbon atoms in chains and rings to form large complex molecules. • explain the role and function of the four major categories of macromolecules (lipids, carbohydrates, proteins and nucleic acids). • identify the functions of different types of proteins and recognize the significance that their conformation play in their functions. • describe the structure of enzymes and explain their role in acting as catalysts to control the rate of metabolic reactions. • explain how light is the initial source of energy for most communities. • recognize the equations for photosynthesis and respiration and identify the reactants and products. • describe the role of ATP in the storage and release of chemical energy in the cell. • explain the interrelatedness of photosynthesis and cell respiration.

Standard BIO.2

BIO.2	The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include a) water chemistry and its impact on life processes; b) the structure and function of macromolecules; c) the nature of enzymes; and d) the capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration.

Essential Understandings	Essential Knowledge and Skills
• <u>In multicellular organisms, the fluid within the cell and the fluids surrounding the cells have a characteristic and nearly constant pH. This pH is maintained in a number of ways, and one of the most important is through buffer systems.</u> • Inside every cell is a concentrated mixture of thousands of different macromolecules forming a variety of specialized structures that carry out cell functions, such as energy production, transport, waste disposal, synthesis of new molecules, and storage of genetic material. • Cells can make a variety of macromolecules from a relatively small set of monomers. • The primary functions of carbohydrate macromolecules are to provide and store energy. • The primary functions of lipid macromolecules are to insulate, store energy, and make up cell membranes. • Nucleic acids (DNA and RNA) control cell activities by directing protein synthesis. • Proteins are polymers made by linking together amino acid monomers. Protein molecules that are assembled in cells carry out most of the cells' work. The function of each protein molecule depends on its specific conformation. The sequence of amino acids and the shape of the chain are a consequence of attractions between the chain's parts. Some proteins are structural (hair, nails). Others function in transport (hemoglobin), movement (muscle fibers and cytoskeletal elements), defense (antibodies), and regulation of cell functions (hormones and enzymes). ~~A protein's structure depends on its specific conformation.~~ • Most life processes are a series of chemical reactions influenced by	

Standard BIO.2

BIO.2	The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include a) water chemistry and its impact on life processes; b) the structure and function of macromolecules; c) the nature of enzymes; and d) the capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration.

Essential Understandings	Essential Knowledge and Skills
environmental and genetic factors. The chemical reactions that occur inside cells are directly controlled by a large set of protein molecules called enzymes, whose functions depend on their specific shapes. Each enzyme has a definite three-dimensional shape that allows it to recognize and bind with its substrate. In living cells, enzymes control the rate of metabolic reaction by acting as catalysts. • The breakdown of nutrient molecules enables all cells to store energy in specific chemicals that are used to carry out the life functions of the cell. • Plant cells and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy-rich organic compounds and release oxygen into the environment. • ~~Light is the initial source of energy for most communities.~~ The process of photosynthesis provides a vital connection between the sun and the energy needs of living systems. During photosynthesis, cells trap energy from sunlight with chlorophyll, found in chloroplasts, and use the energy, carbon dioxide, and water to produce energy-rich organic molecules (glucose) and oxygen. Photosynthesis involves an energy conversion in which light energy is converted to chemical energy in specialized cells. These cells are found in autotrophs such as plants and some protists. • During cell respiration, eukaryotic cells "burn" organic molecules with oxygen~~, which produces energy, carbon dioxide, and water.~~ in the mitochondria, which releases energy in the form of ATP, carbon dioxide, and water. • Photosynthesis and cell respiration are complementary processes for cycling carbon dioxide and oxygen as well as transferring energy in ecosystems.	

Standard BIO.2

BIO.2	The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include a) water chemistry and its impact on life processes; b) the structure and function of macromolecules; c) the nature of enzymes; and d) the capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration.

Essential Understandings	Essential Knowledge and Skills
• Cells release the chemical energy stored in the products of photosynthesis. This energy is transported within the cell in the form of ATP. When cells need energy to do work, certain enzymes release the energy stored in the chemical bonds in ATP.	

Standard BIO.3

BIO.3 The student will investigate and understand relationships between cell structure and function. Key concepts include

a) evidence supporting the cell theory;
b) characteristics of prokaryotic and eukaryotic cells;
c) similarities between the activities of the organelles in a single cell and a whole organism;
d) the cell membrane model; and
e) the impact of surface area to volume ratio on cell division, material transport, and other life processes.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The cell theory is the unifying theme in biology because it emphasizes the similarity of all living things. The traditional cell theory states that 1) ~~all~~ living things are composed of one or more cells and that cells come from other cells by the process of cell reproduction; 2) ~~C~~cells are the basic units of structure and function of all living things; and 3) ~~C~~cells contain specialized structures to perform functions necessary for life. • The development of the cell theory was accelerated by the ability to make observations on a microscopic level. The development and refinement of magnifying lenses and light microscopes made the observation and description of microscopic organisms and living cells possible. • Continued advances in microscopy allowed observation of cell organelles and ultrastructure. Current technology allows the observation of cellular processes underlying both cell structure and function. • As a result of additional study and the integration of studies of cell life functions, a modern cell theory has been developed. The modern cell theory, in addition to the tenants of the traditional cell theory, states 1) energy flow (metabolism and biochemistry) occurs within cells; 2) cells contain hereditary information (DNA) that is passed from cell to cell during cell division; and 3) all cells are basically the same in chemical composition in organisms of similar species . • Cell structure is one of the ways in which organisms differ from each other. The diversity that exists ranges from simple prokaryotic cells to complex multicellular organisms. • The simplest life forms exhibiting cellular structure are the prokaryotes.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • describe the key events leading to the development of the cell theory. • compare and contrast characteristics of prokaryotic and eukaryotic cells. • compare and contrast the activities of an organelle in a single cell and a whole organism. • identify the following essential cell structures and their functions ~~include~~ - the nucleus (contains DNA; site where RNA is made) - ribosome (site of protein synthesis) - mitochondrion (site of cell respiration) - chloroplast (site of photosynthesis) - endoplasmic reticulum (transports materials through the cell) - Golgi (site where cell products are packaged for export) - lysosome (contains digestive enzymes) - cell membrane (controls what enters and leaves the cell) - cell wall (provides support) - vacuole (storage of material) - cytoplasm (contains organelles and site of many chemical reactions) - centriole (organizes spindle fibers in animal cells) - cytoskeleton • describe how the selective permeability of the cell membrane affects the life of a cell. • describe processes associated with movement across the membrane for diffusion, facilitated diffusion, osmosis, and active transport.

Standard BIO.3

BIO.3	The student will investigate and understand relationships between cell structure and function. Key concepts include a) evidence supporting the cell theory; b) characteristics of prokaryotic and eukaryotic cells; c) similarities between the activities of the organelles in a single cell and a whole organism; d) the cell membrane model; and e) the impact of surface area to volume ratio on cell division, material transport, and other life processes.

Essential Understandings	Essential Knowledge and Skills
Earth's first cells were prokaryotes. Prokaryotic cells exist in two major forms: eubacteria and archaebacteria. Prokaryotes are ~~the~~ Earth's most abundant inhabitants. They can survive in a wide range of environments and obtain energy in a variety of ways. • ~~Several differences between eukaryotes and prokaryotes include~~ Eukaryotes differ from prokaryotes based on size, genetic material surrounded by a nuclear membrane, and the addition of membrane bound organelles (i.e., mitochondria and chloroplasts). • Eukaryotes arose from prokaryotes and developed into larger more complex organisms, from single-celled protists to multicellular protists, fungi, plants, and animals. • Some organisms exist as a single cell, while others are composed of many cells, each specialized to perform distinct metabolic functions. The basic processes necessary for living things to survive are the same for a single cell as they are for a more complex organism. A single-celled organism has to conduct all life processes by itself. A multicellular organism has groups of cells that specialize to perform specific functions. • ~~Cell specialization occurs during the development of a multicellular organism. The genetic information necessary for all cellular functions remains in each cell but may not be used.~~ • Cellular activities necessary for life include chemical reactions that facilitate acquiring energy, reproduction, and ~~adaptation/~~maintaining homeostasis. Relationships between structure and function can be examined at each of the hierarchical levels of organization: molecular, cellular, organism, population, community, and ecosystem. • Cellular differences between plant and animal cells include the presence	• describe the relationship between a cell's external solute concentration and its effect on the cell's internal solute concentration. • compare the efficiency of the ability of a cell to transport material based on surface area to volume ratios.

Standard BIO.3

BIO.3	The student will investigate and understand relationships between cell structure and function. Key concepts include a) evidence supporting the cell theory; b) characteristics of prokaryotic and eukaryotic cells; c) similarities between the activities of the organelles in a single cell and a whole organism; d) the cell membrane model; and e) the impact of surface area to volume ratio on cell division, material transport, and other life processes.

Essential Understandings	Essential Knowledge and Skills
of a cell wall that gives the plant cell a defined shape, the presence of chloroplast, and the number of vacuoles. • The fluid mosaic model of a membrane emphasizes the arrangement and function of a bilayer of phospholipids, transport proteins, and cholesterol. • Homeostasis of a cell is maintained by ~~a~~ the plasma membrane comprised of a variety of organic molecules. ~~that~~ The membrane controls the movement of material in and out of the cell, communication between cells, and the recognition of cells to facilitate multiple metabolic functions. • Diffusion occurs in cells when substances (oxygen, carbon dioxide, salts, sugars, amino acids) that are dissolved in water move from an area of higher concentration to an area of lower concentration. • Facilitated diffusion occurs in cells when larger substances are moved from an area of higher concentration to an area of lower concentration with the assistance of a carrier protein without the use of energy. • Osmosis refers to the movement of water molecules through a semi-permeable membrane from an area of greater water concentration or pressure (lower solute concentration) to an area of lesser water concentration or pressure (higher solute concentration). • Active transport refers to the movement of solid ~~and~~ or liquid particles into and out of a cell with an input of energy. • As cells increase in size, surface area to volume ratios decrease, making cells unable to obtain nutrients or remove wastes. To reduce the effects of this, cells divide to stay small or change shape to increase surface area or reduce volume.	

Standard BIO.4

BIO.4 The student will investigate and understand life functions of Archaea, Bacteria and Eukarya. Key concepts include

a) comparison of their metabolic activities;
b) maintenance of homeostasis;
c) how the structures and functions vary among and within the Eukarya kingdoms of protists, fungi, plants, and animals, including humans;
d) human health issues, human anatomy, and body systems;
e) how viruses compare with organisms; and
f) evidence supporting the germ theory of infectious disease.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The ~~millions of different~~ organisms that live on Earth today share many structural and metabolic features, including cellular organization, common molecular mechanisms for energy transformation, ~~and~~ utilization and maintenance of homeostasis, common genetic code, and mechanisms for the transmission of traits from one generation to the next. • The diversity that is evident in the natural world can be studied in the local environment in the context of variations on a common theme. • Understanding normal body functioning assists in understanding situations~~, both hereditary and environmental, in which~~ when functioning is impaired. • Like other organisms, human beings are composed of groups of cells (tissues, organs, and organ systems) that are specialized to provide the human organism with the basic requirements for life: obtaining food and deriving energy from it, maintaining homeostasis, coordinating body functions, and reproducing. • Organ systems function and interact to maintain a stable internal environment that can resist disturbance from within or without (homeostasis). • For the body to use food for energy, the food must first be digested into molecules that are absorbed and transported to cells, where the food is used for energy and for repair and growth. To burn food for the release of energy, oxygen must be supplied to cells and carbon dioxide removed. The respiratory system responds to changing demands by increasing or decreasing breathing rate in order to maintain homeostasis.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • compare and contrast the metabolic activities of all domains of life. • identify the proper response an organism would exhibit in response to changes in the environment to maintain homeostasis. • categorize and compare the Eukarya kingdoms based on cell structure, locomotion, reproduction, response to the environment and metabolism. • identify the main factors that affect human health. • describe the major functions of the human body systems and the role of each in maintaining homeostasis. • compare and contrast a virus and a cell in relation to genetic material and reproduction. • describe how Pasteur's and Koch's experimentation and hypotheses led to an understanding of the presence of microorganisms and their relationship to diseases. • ~~differentiate and give examples of the following from local ecosystems:~~ - ~~autotrophs and heterotrophs (producers, consumers, and decomposers)~~ - ~~multicellular and unicellular organisms~~ - ~~motile and non-motile organisms~~ - ~~organisms with and without cell walls~~ - ~~sexually and asexually reproducing organisms~~ - ~~aquatic and terrestrial organisms~~

Standard BIO.4

BIO.4	The student will investigate and understand life functions of Archaea, Bacteria and Eukarya. Key concepts include a) comparison of their metabolic activities; b) maintenance of homeostasis; c) how the structures and functions vary among and within the Eukarya kingdoms of protists, fungi, plants, and animals, including humans; d) human health issues, human anatomy, and body systems; e) how viruses compare with organisms; and f) evidence supporting the germ theory of infectious disease.

Essential Understandings	Essential Knowledge and Skills
• The circulatory system, which moves all of these substances to or from cells, responds to changing demands by increasing or decreasing heart rate and blood flow in order to maintain homeostasis. • The urinary system disposes of dissolved waste molecules; the intestinal tract removes solid wastes; and the skin and lungs rid the body of ~~heat~~ thermal energy. • Specialized cells of the immune system and the molecules they produce are designed to protect against organisms and substances that enter from outside the body and against some cancer cells that arise from within. • Communication between cells is required for coordination of body functions. The nerves communicate with electrochemical signals, hormones circulate through the blood, and some cells secrete substances that spread only to nearby cells. • Environmental factors that impact human health include diet, exercise, sleep, stress, toxic substances that enter the body, viruses, and other living organisms that infect the body. • Genetic predisposition towards diseases impacts human health. Awareness of genetic predisposition allows individuals to make lifestyle changes that can enhance quality of life. • Viruses do not share many of the characteristics of living organisms. Viruses are not cells. Basic viral structure consists of a nucleic acid core surrounded by a protein coat. Viruses can reproduce only inside a living cell, the host cell. • The viral reproductive process includes the following steps: - A virus must insert its genetic material into the host cell.	- ~~behavioral responses to the environment.~~

Standard BIO.4

BIO.4	The student will investigate and understand life functions of Archaea, Bacteria and Eukarya. Key concepts include a) comparison of their metabolic activities; b) maintenance of homeostasis; c) how the structures and functions vary among and within the Eukarya kingdoms of protists, fungi, plants, and animals, including humans; d) human health issues, human anatomy, and body systems; e) how viruses compare with organisms; and f) evidence supporting the germ theory of infectious disease.

Essential Understandings	Essential Knowledge and Skills
- The viral genetic material takes control of the host cell and uses it to produce viruses. - The newly formed viruses are released from the host cell. • Throughout history, people have created explanations for disease. The introduction of the germ theory led to the understanding that many diseases are caused by microorganisms. Changes in health practices have resulted from the acceptance of the germ theory of disease. • Modern health practices emphasize sanitation, the safe handling of food and water, aseptic techniques to keep germs out of the body, and the development of vaccinations and other chemicals and processes to destroy microorganisms.	

Standard BIO.5

BIO.5	The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include a) cell growth and division; b) gamete formation; c) cell specialization; d) prediction of inheritance of traits based on the Mendelian laws of heredity; e) historical development of the structural model of DNA; f) genetic variation; g) the structure, function, and replication of nucleic acids; h) events involved in the construction of proteins; i) use, limitations, and misuse of genetic information; and j) exploration of the impact of DNA technologies.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • All living cells come from other living cells. A typical cell goes through a process of growth, development, and reproduction called the cell cycle. • Mitosis produces two genetically identical cells. During mitosis, the nucleus of the cell divides, forming two nuclei with identical genetic information. Mitosis is referred to in the following stages: prophase, metaphase, anaphase, and telophase. • Many organisms are capable of combining genetic information from two parents to produce offspring. Sex cells are produced through meiosis. This allows sexually reproducing organisms to produce genetically differing offspring, and maintain their number of chromosomes. Meiosis occurs in sexual reproduction when a diploid germ cell produces four haploid daughter cells that can mature to become gametes (sperm or egg). • Genetically diverse populations are more likely to survive changing environments. Recombination and mutation provide for genetic diversity. Some new gene combinations have little effect, some can produce organisms that are better suited to their environments, and others can be deleterious. • Mitosis and meiosis refer to division of the nuclear material.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • create a diagram to model the stages of mitosis and explain the processes occurring at each stage. • describe the importance of cell specialization in the development of multicellular organisms. • create a diagram to model the stages of meiosis and explain the processes occurring at each stage. • compare and contrast the process of mitosis and meiosis and determine under which conditions each process will occur. • explain how the Mendelian laws of heredity apply to the patterns of inheritance. • ~~predict possible gametes in a dihybrid cross, given parental genotypes~~. • identify the traits expressed from a given genotype. • use a Punnett square to show all possible combinations of gametes and the likelihood that particular combinations will occur in monohybrid and dihybrid crosses. • evaluate karyotype charts and make a determination of the gender

Standard BIO.5

BIO.5 The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

a) cell growth and division;
b) gamete formation;
c) cell specialization;
d) prediction of inheritance of traits based on the Mendelian laws of heredity;
e) historical development of the structural model of DNA;
f) genetic variation;
g) the structure, function, and replication of nucleic acids;
h) events involved in the construction of proteins;
i) use, limitations, and misuse of genetic information; and
j) exploration of the impact of DNA technologies.

Essential Understandings	Essential Knowledge and Skills
Cytokinesis is the division of the cytoplasm and organelles. • The many body cells of an organism can be specialized to perform different functions, even though they are all descended from a single cell and contain essentially the same genetic information. • Mendel's laws of heredity are based on his mathematical analysis of observations of patterns of inheritance of traits. Geneticists apply mathematical principles of probability to Mendel's laws of heredity in order to predict the results of simple genetic crosses. The laws of probability govern simple genetic recombinations. • Genotype describes the genetic make-up of an organism and phenotype describes the organism's appearance based on its genes. Homozygous individuals have two identical alleles for a particular trait, while heterozygous individuals have contrasting alleles. When one allele masks the effect of another, that allele is called dominant and the other recessive. When an intermediate phenotype occurs and no allele dominates, incomplete dominance results. Many other patterns of inheritance exist including multiple alleles, polygenic inheritance, and sex-linked inheritance. • Once DNA was shown to be the genetic material, a race among scientists took place to work out its structure. Studies of the amounts of each DNA base in different organisms led to the concept of complementary base-paring. Interpretations of X-ray photographs of DNA were used to describe the shape and dimensions of the molecule.	and genetic health of the individual. • provide examples of reasons for genetic diversity and why it can be an advantage for populations. • provide examples of mutations that are lethal, harmful, and beneficial. • describe the basic structure of DNA and its function in inheritance. • describe the key events leading to the development of the structural model of DNA. • given a DNA sequence, write a complementary mRNA strand (A-U, T-A, C-G and G-C). • explain the process of DNA replication. • explain the process of protein synthesis, including DNA transcription and translation. • evaluate examples of genetic engineering and the potential for controversy. • describe the uses, limitations, and potential for misuse of genetic information.

Standard BIO.5

BIO.5	The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include a) cell growth and division; b) gamete formation; c) cell specialization; d) prediction of inheritance of traits based on the Mendelian laws of heredity; e) historical development of the structural model of DNA; f) genetic variation; g) the structure, function, and replication of nucleic acids; h) events involved in the construction of proteins; i) use, limitations, and misuse of genetic information; and j) exploration of the impact of DNA technologies.

Essential Understandings	Essential Knowledge and Skills
An analysis of this and other available data led to a structural model for the DNA double helix. • DNA is a polymer consisting of nucleotides. A DNA nucleotide is identified by the base it contains: adenine (A), guanine (G), ~~and~~ cytosine (C) or thymine (T). DNA is a double-stranded molecule. The strands are <u>composed of covalently bonded sugar and phosphate molecules and are</u> connected by complementary nucleotide pairs (A-T and C-G) like rungs on a ladder. The ladder twists to form a double helix. • The double helix model explained how heredity information is transmitted and provided the basis for an explosion of scientific research in molecular genetics. The sorting and recombination of genes in sexual reproduction results in a great variety of gene combinations in the offspring of any two parents. • The genetic code is a sequence of DNA nucleotides in the nucleus of eukaryotic cells. Before a cell divides, the instructions are duplicated so that each of the two new cells gets all the necessary information for carrying on life functions. Cells pass on their genetic code by replicating ~~(copying)~~ their DNA. • DNA stores the information for directing the construction of proteins within a cell. These proteins determine the phenotype of an organism. The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. The code is virtually the same for all life forms.	

Standard BIO.5

BIO.5	The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include a) cell growth and division; b) gamete formation; c) cell specialization; d) prediction of inheritance of traits based on the Mendelian laws of heredity; e) historical development of the structural model of DNA; f) genetic variation; g) the structure, function, and replication of nucleic acids; h) events involved in the construction of proteins; i) use, limitations, and misuse of genetic information; and j) exploration of the impact of DNA technologies.

Essential Understandings	Essential Knowledge and Skills
• During DNA replication, enzymes unwind and unzip the double helix and each strand serves as a template for building a new DNA molecule. Free nucleotides bond to the template (A-T and C-G) forming a complementary strand. The final product of replication is two identical DNA molecules. • Inserting, deleting, or substituting DNA bases can alter genes. An altered gene may be passed on to every cell that develops from it, causing an altered phenotype. An altered phenotype may be neutral, beneficial or detrimental. Sometimes entire chromosomes can be added or deleted, resulting in a genetic disorder ~~such as Trisomy 21 (Down syndrome)~~. These abnormalities may be diagnosed using a Karyotype. • In order for cells to make proteins, the DNA code must be transcribed (copied) to messenger RNA (mRNA). The mRNA carries the code from the nucleus to the ribosomes in the cytoplasm. RNA is a single-stranded polymer of four nucleotide monomers. A RNA nucleotide is identified by the base it contains: adenine (A), guanine (G), and cytosine (C) or uracil (U). • At the ribosome, amino acids are linked together to form specific proteins. The amino acid sequence is ~~directed~~ determined by the mRNA molecule. • DNA technologies allow scientists to identify, study, and modify genes. Forensic identification is an example of the application of DNA technology.	

Standard BIO.5

BIO.5	The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include a) cell growth and division; b) gamete formation; c) cell specialization; d) prediction of inheritance of traits based on the Mendelian laws of heredity; e) historical development of the structural model of DNA; f) genetic variation; g) the structure, function, and replication of nucleic acids; h) events involved in the construction of proteins; i) use, limitations, and misuse of genetic information; and j) exploration of the impact of DNA technologies.

Essential Understandings	Essential Knowledge and Skills
• Genetic engineering techniques are used in a variety of industries, in agriculture, in basic research, and in medicine. There is great ~~potential for the development of~~ benefit in terms of useful products derived through genetic engineering (e.g., human growth hormone, insulin, and pest- and disease-resistant fruits and vegetables). • Eugenics, a pseudo-science of selective procreation, was a movement throughout the twentieth century, worldwide as well as in Virginia, that demonstrated a misuse of the principles of heredity. • The Human Genome Project is a collaborative effort to map the entire gene sequence of organisms. This information ~~will be~~ may be useful in detection, prevention, and treatment of many genetic diseases. The potential for identifying and altering genomes raises practical and ethical questions. • Cloning is the production of genetically identical cells and/or organisms.	

Standard BIO.6

BIO.6 The student will investigate and understand bases for modern classification systems. Key concepts include

a) structural similarities among organisms;
b) fossil record interpretation;
c) comparison of developmental stages in different organisms;
d) examination of biochemical similarities and differences among organisms; and
e) systems of classification that are adaptable to new scientific discoveries.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities that reflect their relationships over a period of time. • Binomial nomenclature is a standard way of identifying a species with a scientific two-word name. The first word is the genus name and the second the species name. Species is the basic unit of classification. A species is defined as a group of organisms that has the ability to interbreed and produce fertile offspring in nature. • A dichotomous key is a classification tool used to identify and organize organisms using defining characteristics. • Information about relationships among living organisms and those that inhabited Earth in the past is gained by comparing biochemistry and developmental stages of organisms and by examining and interpreting the fossil record. This information is continually being gathered and used to modify and clarify existing classification systems. • Evolutionary relationships can be represented using a branching diagram called a cladogram or phylogenetic tree which are organized by shared, derived characteristics. • Similarities among organisms on the structural and metabolic levels are reflected in the large degree of similarity in proteins and nucleic acids of different organisms. Diversity is the product of variations in these molecules. • ~~Investigations of local flora and fauna provide opportunities to enhance understanding and stimulate interest in local environmental issues by~~	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • construct and utilize dichotomous keys to classify groups of objects and organisms. • describe relationships based on homologous structures. • compare structural characteristics of an extinct organism, as evidenced by its fossil record, with present, familiar organisms. • recognize similarities in embryonic stages in diverse organisms in the animal kingdom, from zygote through embryo and infer relationships. • ~~describe relationships between organisms, given amino acid or nucleotide sequences.~~ • compare biochemical evidence (DNA sequences, amino acid sequences) and describe relationships. • interpret a ~~clad gram~~ cladogram or phylogenic tree showing evolutionary relationships among organisms. • investigate flora and fauna in field investigations and apply classification systems.

Standard BIO.6

BIO.6	The student will investigate and understand bases for modern classification systems. Key concepts include a) structural similarities among organisms; b) fossil record interpretation; c) comparison of developmental stages in different organisms; d) examination of biochemical similarities and differences among organisms; and e) systems of classification that are adaptable to new scientific discoveries.

Essential Understandings	Essential Knowledge and Skills
~~developing and applying classification systems in the field.~~	

Standard BIO.7

BIO.7 The student will investigate and understand how populations change through time. Key concepts include

a) evidence found in fossil records;
b) how genetic variation, reproductive strategies, and environmental pressures impact the survival of populations;
c) how natural selection leads to adaptations;
d) emergence of new species; and
e) scientific evidence and explanations for biological evolution.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • A fossil is any evidence of an organism that lived long ago. Scientists have used the fossil record to construct a history of life on Earth. Although there is not a complete record of ancient life for the past 3.5 billion years, a great deal of modern knowledge about the history of life comes from the fossil record. • ~~Scientists have developed hypotheses about conditions on early Earth that could have led to the formation of the first organic molecules, early self-replicating molecules, the source of free oxygen in Earth's atmosphere, and the appearance of prokaryotic and later eukaryotic cells.~~ • Populations are groups of interbreeding individuals that live in the same place at the same time and compete with each other for food, water, shelter, and mates. Populations produce more offspring than the environment can support. Organisms with certain genetic variations will be favored to survive and pass their variations on to the next generation. The unequal ability of individuals to survive and reproduce leads to the gradual change in a population, generation after generation over many generations. Depending on the selective pressure, these changes can be rapid over few generations (ie., antibiotic resistance) • Genetic mutations and variety produced by sexual reproduction allow for diversity within a given population. Many factors can cause a change in a gene over time. Mutations are important in how populations change over time because they result in ~~genetic~~ changes to the gene pool. • Through his observations, including those made in the Galapagos Islands, Charles Darwin formulated a theory of how species change over	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • determine the relative age of a fossil given information about its position in the rock and absolute dating by radioactive decay. • differentiate between relative and absolute dating based on fossils in biological evolution. • recognize that adaptations may occur in populations of organisms over a period of time. • describe the impact of reproductive strategies and rates on a population's survival. • describe how genetic variation can lead to gradual changes in populations and the emergence of new species over time. • predict the impact of environmental pressures on populations. • explain how natural selection leads to changes in gene frequency in a population over time. • compare and contrast punctuated equilibrium with gradual change over time.

Standard BIO.7

BIO.7	The student will investigate and understand how populations change through time. Key concepts include a) evidence found in fossil records; b) how genetic variation, reproductive strategies, and environmental pressures impact the survival of populations; c) how natural selection leads to adaptations; d) emergence of new species; and e) scientific evidence and explanations for biological evolution.

Essential Understandings	Essential Knowledge and Skills
time, called natural selection. Natural selection is a process by which organisms with traits well suited to an environment survive and reproduce at a greater rate than organisms less suited to that environment~~.~~, and ~~Natural selection~~ is governed by the principles of genetics. The change in frequency of a gene in a given population leads to a change favoring maintenance of that gene within a population and if so, may result in the emergence of a new species. Natural selection operates on populations over many generations. • Depending on the rate of adaptation, the rate of reproduction, and the environmental factors present, structural adaptations may take millions of years to develop. • Adaptations sometimes arise abruptly in response to strong environmental selective pressures, for example, the development of antibiotic resistance in bacterial populations, morphological changes in the peppered moth population, the development of pesticide resistance in insect populations. • Stephen Jay Gould's idea of *punctuated equilibrium* proposes that organisms may undergo rapid (in geologic time) bursts of speciation followed by long periods of time unchanged. This view is in contrast to the traditional evolutionary view of gradual and continuous change.	

Standard BIO.8

BIO.8 The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include

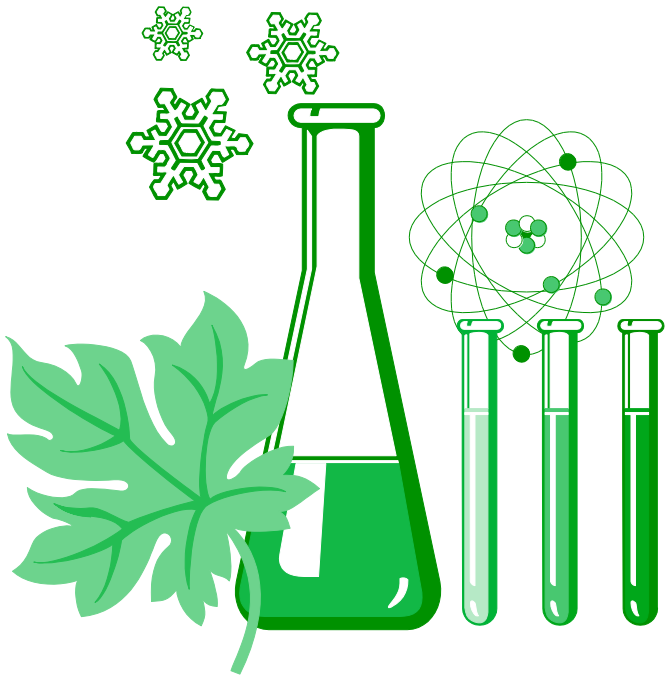
a) interactions within and among populations including carrying capacities, limiting factors, and growth curves;
b) nutrient cycling with energy flow through ecosystems;
c) succession patterns in ecosystems;
d) the effects of natural events and human activities on ecosystems; and
e) analysis of the flora, fauna, and microorganisms of Virginia ecosystems.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • As any population of organisms grows, it is held in check by interactions among a variety of biotic and abiotic factors. • Abiotic factors are the nonliving elements in an ecosystem, such as temperature, moisture, air, salinity, and pH. Biotic factors are all the living organisms that inhabit the environment, including predators, food sources, and competitors. • Population growth curves exhibit many characteristics, such as initial growth stage, exponential growth, steady state, decline, and extinction. Limiting factors are the components of the environment that restrict the growth of populations. Carrying capacity is the number of organisms that can be supported by the resources in an ecosystem. • A community is a collection of interacting populations. • Symbiosis is a close and permanent relationship between organisms of two different species. Examples include mutualism, commensalism, and parasitism. • Ecosystems demonstrate an exchange of energy and nutrients among inhabiting organisms. ~~The gradual change in an ecosystem that occurs as communities slowly replace one another is known as *ecological succession*.~~ • An ecosystem consists of all the interacting species and the abiotic environment in a given geographic area. All matter including essential ~~N~~nutrients cycle through an ecosystem. The most common examples of such matter and nutrients include carbon, ~~oxygen,~~ nitrogen, and water. • Energy flows in an ecosystem from producers to various levels of	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • graph and interpret a population growth curve and identify the carrying capacity of the populations. • make predictions about changes that could occur in population numbers as the result of population interactions. • illustrate and/or model the key processes in the water, carbon, and nitrogen cycle and explain the role of living things in each of the cycles. • given an illustration of a food chain and a food web, identify each organism as a producer (autotroph), consumer (primary/second order), or decomposer and describe their role in the ecosystem. • interpret how the flow of energy occurs between trophic levels in all ecosystems ~~and can be depicted as follows~~ in each of the following: - food chain - food web - pyramid of energy - pyramid of biomass - pyramid of numbers. • identify and describe an ecosystem in terms of the following: - effects of biotic and abiotic components - examples of interdependence - evidence of human influences - energy flow and nutrient cycling - diversity analysis

Standard BIO.8

BIO.8	The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include a) interactions within and among populations including carrying capacities, limiting factors, and growth curves; b) nutrient cycling with energy flow through ecosystems; c) succession patterns in ecosystems; d) the effects of natural events and human activities on ecosystems; and e) analysis of the flora, fauna, and microorganisms of Virginia ecosystems.

Essential Understandings	Essential Knowledge and Skills
consumers and decomposers. This flow of energy can be diagramed using a food chain or food web. The efficiency of this flow of energy is represented by an energy pyramid. • Ecological succession is a ~~series of changes in a community in which new populations of organisms gradually replace existing ones~~ predictable change in the sequence of species that establish in a particular area over time. • A climax community occurs when succession slows down and a stable community is established. ~~The climax community is made up of organisms that are successful at competing for resources in a given environment.~~ The climax community in most of Virginia is a deciduous oak-hickory (hardwood) forest. • As the human population increases, so does human impact on the environment. Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the ~~atmosphere~~ environment, and intensive farming, have changed the Earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms. • ~~Investigations of local ecosystems provide opportunities for students to enhance their understanding and stimulate their interest in local environmental issues by applying ecological principles in the field.~~	• describe the patterns of succession found in aquatic and terrestrial ecosystems of Virginia. • identify the similarities and differences between primary and secondary succession. • describe the characteristics of a climax community. • ~~Observe and identify flora and fauna in a local community,~~ use local ecosystems to apply ecological principles in the classroom and in the field where appropriate, using field guides and dichotomous keys for identifying and describing ~~organisms~~ flora and fauna that characterize the local ecosystem. • evaluate examples of human activities that have negative and positive impacts on Virginia's ecosystems. • recognize that the Chesapeake Bay watershed includes the majority of Virginia and human activities play an important role in its health.



Science Standards of Learning Curriculum Framework

Chemistry

Final Review
November 18, 2010

Commonwealth of Virginia
Board of Education
Richmond, Virginia
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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning Curriculum Framework* amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The *Science Curriculum Framework* provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (6 – Physics); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard
This section includes background information for the teacher (K-5). It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan lessons focusing on the standard.

Essential Understandings
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Standard CH.1

CH.1 The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include

a) designated laboratory techniques;
b) safe use of chemicals and equipment;
c) proper response to emergency situations;
d) manipulation of multiple variables, using repeated trials;
e) accurate recording, organization, and analysis of data through repeated trials;
f) mathematical and procedural error analysis;
g) mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis;
h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data, communicating results, and using simulations to model concepts;
i) construction and defense of a scientific viewpoint; and
j) the use of current applications to reinforce chemistry concepts.

Essential Understandings

The concepts developed in this standard include the following:

- The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts
  a) the natural world is understandable;
  b) science is based on evidence - both observational and experimental;
  c) science is a blend of logic and innovation;
  d) scientific ideas are durable yet subject to change as new data are collected;
  e) science is a complex social endeavor; and
  f) scientists try to remain objective and engage in peer review to help avoid bias.
- Techniques for experimentation involve the identification and the proper use of chemicals, the description of equipment, and the recommended statewide framework for high school laboratory safety.
- Measurements are useful in gathering data about chemicals and how they behave.
- Repeated trials during experimentation ensure verifiable data.

Essential Knowledge and Skills

~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will

- make connections between components of the nature of science and their investigations and the greater body of scientific knowledge and research.
- demonstrate safe laboratory practices, procedures, and techniques.
- demonstrate the following basic lab techniques: filtering, ~~decanting~~, using chromatography, and lighting a gas burner.
- understand Material Safety Data Sheet (MSDS) warnings, including handling chemicals, lethal dose (LD), hazards, disposal, and chemical spill cleanup.
- identify the following basic lab equipment: beaker, Erlenmeyer flask, graduated cylinder, test tube, test tube rack, test tube holder, ring stand, wire gauze, clay triangle, crucible with lid, ~~evaporation~~ evaporating dish, watch glass, wash bottle, and dropping pipette.
- make the following measurements, using the specified equipment:
  - volume: graduated cylinder, ~~pipette,~~ volumetric flask, buret
  - mass: ~~electronic or dial-a-gram~~ triple beam and electronic balances
  - temperature: thermometer and/or temperature probe

Standard CH.1

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b) safe use of chemicals and equipment;
c) proper response to emergency situations;
d) manipulation of multiple variables, using repeated trials;
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f) mathematical and procedural error analysis;
g) mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis;
h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data, communicating results, and using simulations to model concepts;
i) construction and defense of a scientific viewpoint; and
j) the use of current applications to reinforce chemistry concepts.

Essential Understandings	Essential Knowledge and Skills
• Data tables are used to record and organize measurements. • Mathematical procedures are used to validate data~~.~~, including percent error to evaluate accuracy. • Measurements of quantity include length, volume, mass, temperature, time, and pressure to the correct number of significant digits. Measurements must be expressed in International System of Units (SI) units. • Scientific notation is used to write very small and very large numbers. • Algebraic equations represent relationships between dependent and independent variables. • Graphs are used to summarize the relationship between the independent and dependent variable. • Graphed data give a picture of a relationship. • Ratios and proportions are used in calculations. • Significant digits of a measurement are the number of known digits together with one estimated digit. • The last digit of any valid measurement must be estimated and is	- pressure: barometer and/or pressure probe. • identify, locate, and know how to use laboratory safety equipment, including aprons, goggles, gloves, fire extinguishers, fire blanket, safety shower, eye wash, broken glass container, and fume hood. • design and perform controlled experiments to test predictions, including the following key components: hypotheses, independent and dependent variables, constants, controls, and repeated trials. • ~~Identify variables.~~ • predict outcome(s) when a variable is changed. • read measurements and record data, ~~using~~ reporting the significant digits of the measuring equipment. • demonstrate precision (reproducibility) in measurement. • recognize accuracy in terms of closeness to the true value of a measurement. • determine the mean of a set of measurements. • use data collected to calculate percent error. • discover and eliminate procedural errors.

Standard CH.1

CH.1	The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include a) designated laboratory techniques; b) safe use of chemicals and equipment; c) proper response to emergency situations; d) manipulation of multiple variables, using repeated trials; e) accurate recording, organization, and analysis of data through repeated trials; f) mathematical and procedural error analysis; g) mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis; h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data, communicating results, and using simulations to model concepts; i) construction and defense of a scientific viewpoint; and j) the use of current applications to reinforce chemistry concepts.

Essential Understandings	Essential Knowledge and Skills
therefore uncertain. • Dimensional analysis is a way of translating a measurement from one unit to another unit. • Graphing calculators can be used to manage the mathematics of chemistry. • Scientific questions drive new technologies that allow discovery of additional data and generate better questions. New tools and instruments provide an increased understanding of matter at the atomic, nano and molecular scale. • Constant reevaluation in the light of new data is essential to keeping scientific knowledge current. In this fashion, all forms of scientific knowledge remain flexible and may be revised as new data and new ways of looking at existing data become available.	• ~~know most frequently used~~ use common SI prefixes and their values (milli-, centi-, ~~deci -~~, kilo-) in measurements and calculations. • demonstrate the use of scientific notation, using the correct number of significant digits with powers of ten notation for the decimal place. • ~~Correctly utilize the following when graphing~~ graph data utilizing the following: - independent variable (horizontal axis) - dependent variable (vertical axis) - scale and units of a graph - regression line (best fit curve). • calculate mole ratios, percent composition, conversions, and ~~relative~~ average atomic mass. • ~~Use the rules for performing operations~~ perform calculations ~~with~~ according to significant digits rules. • ~~utilize~~ convert measurements using dimensional analysis. • use graphing calculators to solve chemistry problems. • read a measurement from a graduated scale, stating measured digits plus the estimated digit.

Standard CH.1

CH.1	The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include a) designated laboratory techniques; b) safe use of chemicals and equipment; c) proper response to emergency situations; d) manipulation of multiple variables, using repeated trials; e) accurate recording, organization, and analysis of data through repeated trials; f) mathematical and procedural error analysis; g) mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis; h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data, communicating results, and using simulations to model concepts; i) construction and defense of a scientific viewpoint; and j) the use of current applications to reinforce chemistry concepts.

Essential Understandings	Essential Knowledge and Skills
	• use appropriate technology for data collection and analysis, including probeware interfaced to a graphing calculator and/or computer and computer simulations. • ~~use probeware to gather data.~~ • summarize knowledge gained through gathering and appropriate processing of data in a report that documents background, objective(s), data collection, data analysis and conclusions. • explain the emergence of modern theories based on historical development. For example, students should be able to explain the origin of the atomic theory beginning with the Greek atomists and continuing through the most modern ~~Q~~quantum models.

Standard CH.2

CH.2	The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of a) average atomic mass, mass number, and atomic number; b) isotopes, half lives, and radioactive decay; c) mass and charge characteristics of subatomic particles; d) families or groups; e) periods; f) trends including atomic radii, electronegativity, shielding effect, and ionization energy; g) electron configurations, valence electrons, and oxidation numbers; h) chemical and physical properties; and i) historical and quantum models.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The periodic table is arranged in order of increasing atomic number~~s~~. • The atomic number of an element is the same as the number of protons. In a neutral atom, the number of electrons is the same as the number of protons. All atoms of an element have the same number of protons. • The average atomic mass for each element is the weighted average of that element's naturally occurring isotopes. • The mass number of an element is the sum of the number of protons and neutrons. It is different for each element's isotopes. • An isotope is an atom that has the same number of protons as another atom of the same element but has a different number of neutrons. Some isotopes are radioactive; many are not. • Half-life is the length of time required for half of a given sample of a radioactive isotope to decay. • Electrons have little mass and a negative (–) charge. They are located in electron clouds or probability clouds outside the nucleus. • Protons have a positive (+) charge. Neutrons have no charge. Protons and neutrons are located in the nucleus of the atom and comprise most	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • ~~Using a periodic chart,~~ determine the atomic number, atomic mass, the number of protons, and the number of electrons~~, and the number of neutrons~~ of any ~~neutral~~ atom of a particular element using a periodic table. • determine the number of neutrons in an isotope given its mass number. • perform calculations to determine the "weighted" average atomic mass. • ~~determine~~ perform calculations involving the half-life of a radioactive substance. • ~~describe~~ differentiate between alpha, beta, and gamma radiation with respect to penetrating power, shielding, and composition. • differentiate between the major atom components (proton, neutron and electron) in terms of location, size, and charge. • distinguish between a group and a period. • identify key groups, periods, and regions of elements on the periodic

Standard CH.2

CH.2 The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

a) average atomic mass, mass number, and atomic number;
b) isotopes, half lives, and radioactive decay;
c) mass and charge characteristics of subatomic particles;
d) families or groups;
e) periods;
f) trends including atomic radii, electronegativity, shielding effect, and ionization energy;
g) electron configurations, valence electrons, and oxidation numbers;
h) chemical and physical properties; and
i) historical and quantum models.

Essential Understandings	Essential Knowledge and Skills
of its mass. Quarks are also located in the nucleus of the atom. • The names of groups and periods on the periodic chart are alkali metals, alkaline earth metals, transition metals, halogens, and noble gases~~, and metalloids~~. • Metalloids have properties of metals and nonmetals. They are located between metals and nonmetals on the periodic table. Some are used in semiconductors. • Periods and groups are named by numbering columns and rows. Horizontal rows called periods have predictable properties based on an increasing number of electrons in the outer ~~orbitals~~ energy levels. Vertical columns called groups or families have similar properties because of their similar valence electron configurations. • The Periodic Law states that when elements are arranged in order of increasing atomic numbers, their physical and chemical properties show a periodic pattern. • Periodicity is regularly repeating patterns or trends in the chemical and physical properties of the elements arranged in the periodic table. • Atomic radius is the measure of the distance between radii of two identical atoms of an element. Atomic radius decreases from left to right and increases from top to bottom within given groups. • Electronegativity is the measure of the attraction of an atom for	table. • identify and explain trends in the periodic table as they relate to ionization energy, electronegativity, shielding effect, and relative sizes. • compare an element's reactivity to the reactivity of other elements in the table. • relate the position of an element on the periodic table to its electron configuration. • ~~use an element's electron configuration to~~ determine the number of valence electrons and possible oxidation numbers from an element's electron configuration. • write the electron configuration for the first 20 elements of the periodic table. • distinguish between physical and chemical properties of metals and nonmetals. • differentiate between pure substances and mixtures and between homogeneous and heterogeneous mixtures. • ~~major insights regarding the atomic model of the atom and~~ identify key contributions of principal scientists ~~include~~ including: - ~~particles~~ *atomos*, initial idea of atom – Democritus

Standard CH.2

CH.2	The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of a) average atomic mass, mass number, and atomic number; b) isotopes, half lives, and radioactive decay; c) mass and charge characteristics of subatomic particles; d) families or groups; e) periods; f) trends including atomic radii, electronegativity, shielding effect, and ionization energy; g) electron configurations, valence electrons, and oxidation numbers; h) chemical and physical properties; and i) historical and quantum models.

Essential Understandings	Essential Knowledge and Skills
electrons in a ~~covalent~~ bond. Electronegativity increases from left to right within a period and decreases from top to bottom within a group. • Shielding effect is constant within a given period and increases within given groups from top to bottom. • Ionization energy is the energy required to remove the most loosely held electron from a neutral atom. Ionization energies generally increase from left to right and decrease from top to bottom of a given group. • Electron configuration is the arrangement of electrons around the nucleus of an atom based on their energy level. • Electrons are added one at a time to the lowest energy levels first (Aufbau Principle). Electrons occupy equal-energy orbitals so that a maximum number of unpaired electrons results (Hund's Rule). • Energy levels are designated 1–7. Orbitals are designated s, p, d, and f according to their shapes ~~s, p, d, f orbitals~~ and relate to the regions of the Periodic Table. An orbital can hold a maximum of two electrons (Pauli Exclusion Principle). • Atoms can gain, lose, or share electrons within the outer energy level. • Loss of electrons from neutral atoms results in the formation of an ion with a positive charge (cation). Gain of electrons by a neutral atom results in the formation of an ion with a negative charge (anion).	- first atomic theory of matter, solid sphere model – John Dalton - discovery of the electron using the cathode ray tube experiment, plum pudding model – J. J. Thom~~p~~son - discovery of the nucleus using the gold foil experiment, nuclear model – Ernest Rutherford - discovery of charge of electron using the oil drop experiment – Robert Millikan - energy levels, planetary model ~~of atom~~ – Niels Bohr - periodic table arranged by atomic mass – D~~e~~mitri~~y~~ Mendeleev - periodic table arranged by atomic number – Henry Moseley - quantum nature of energy – Max Planck - uncertainty principle, quantum mechanical model – Werner Heisenberg - wave theory, quantum mechanical model – Louis de Broglie. - ~~quantum numbers, quantum mechanical model – Erwin Schrödinger.~~ • differentiate between the historical and quantum models of the atom.

Standard CH.2

CH.2	The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of a) average atomic mass, mass number, and atomic number; b) isotopes, half lives, and radioactive decay; c) mass and charge characteristics of subatomic particles; d) families or groups; e) periods; f) trends including atomic radii, electronegativity, shielding effect, and ionization energy; g) electron configurations, valence electrons, and oxidation numbers; h) chemical and physical properties; and i) historical and quantum models.

Essential Understandings	Essential Knowledge and Skills
• Transition metals can have multiple oxidation states. • Matter occurs as elements (pure), compounds (pure), and mixtures, which may be homogeneous (solutions) or heterogeneous. Some elements, such as oxygen, hydrogen, fluorine, chlorine, bromine, iodine, and nitrogen, naturally occur as diatomic molecules. • Matter is classified by its chemical and physical properties. • Physical properties refer to the condition or quality of a substance that can be observed or measured without changing the substance's composition. Important physical properties are density, conductivity, melting point, boiling point, malleability, and ductility. • Chemical properties refer to the ability of a substance to undergo chemical reaction and form a new substance. • Reactivity is the tendency of an element to enter into a chemical reaction. • Discoveries and insights related to the atom's structure have changed the model of the atom over time. Historical models have included solid sphere, plum pudding, nuclear, and planetary models. The modern atomic theory is called the ~~Q~~quantum ~~M~~mechanical ~~M~~model.	

Standard CH.3

CH.3 The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include

a) nomenclature;
b) balancing chemical equations;
c) writing chemical formulas;
d) bonding types;
e) reaction types; and
f) reaction rates, kinetics, and equilibrium.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Chemical formulas are used to represent compounds. Subscripts represent the relative number of each type of atom in a molecule or formula unit. The International Union of Pure and Applied Chemistry (IUPAC) system is used for naming compounds. • When pairs of elements form two or more compounds, the masses of one element that combine with a fixed mass of the other element form simple, whole-number ratios (Law of Multiple Proportions). • ~~Elements and compounds react in different ways.~~ Compounds have different properties than the elements from which they are composed. • Conservation of matter is represented in balanced chemical equations. A coefficient is a quantity that precedes a reactant or product ~~symbol or~~ formula in a chemical equation and indicates the relative number of particles involved in the reaction. • The empirical formula shows the simplest whole-number ratio in which the atoms of the elements are present in the compound. The molecular formula shows the actual number of atoms of each element in one molecule of the substance. • Lewis dot diagrams are used to represent valence electrons in an element. Structural formulas ~~also~~ show the arrangements of atoms and bonds in a molecule and are represented by Lewis dot structures. • Bonds form between atoms to achieve stability. Covalent bonds involve the sharing of electrons between atoms. Ionic bonds involve the transfer of electrons between ions. Elements with low ionization energy form	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • name binary covalent/molecular compounds. • name binary ionic compounds (using the Roman numeral system where appropriate). • predict, draw, and name molecular shapes (bent, linear, trigonal planar, tetrahedral, and trigonal pyramidal). • transform word equations into chemical equations and balance chemical equations. • write the chemical formulas for certain common substances, such as ammonia, water, carbon monoxide, carbon dioxide, sulfur dioxide, and carbon tetrafluoride. • ~~recognize the formulas and names of certain polyatomic ions, such as carbonate, sulfate, nitrate, hydroxide, phosphate, and ammonium, and~~ use ~~these~~ polyatomic ions for naming and writing ~~the~~ formulas of ionic compounds, including carbonate, sulfate, nitrate, hydroxide, phosphate, and ammonium. • draw Lewis dot diagrams to represent valence electrons in elements and draw Lewis dot ~~diagrams~~ structures to show covalent bonding. • use valence shell electron pair repulsion (VSEPR) model to ~~predict,~~ draw and name molecular shapes (bent, linear, trigonal planar, tetrahedral, and trigonal pyramidal). • recognize polar molecules and non-polar molecules.

Standard CH.3

CH.3	The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include a) nomenclature; b) balancing chemical equations; c) writing chemical formulas; d) bonding types; e) reaction types; and f) reaction rates, kinetics, and equilibrium.

Essential Understandings	Essential Knowledge and Skills
positive ions (cations) easily. Elements with high ionization energy form negative ions (anions) easily. Polar bonds form between elements with very different electronegativities. Non-polar bonds form between elements with similar electronegativities. • Polar molecules result when ~~a molecule behaves as if one end were positive and the other end negative~~ electrons are distributed unequally. • ~~Spontaneous reactions may be fast or slow. Randomness (entropy), heat content (enthalpy), and temperature affect spontaneity.~~ • Major types of chemical reactions are - synthesis ($A+B \rightarrow AB$) - decomposition ($BC \rightarrow B+C$) - single replacement ($A+BC \rightarrow B+AC$) - double replacement ($AC+BD \rightarrow AD+BC$) - neutralization ($HX+MOH \rightarrow H_2O + MX$) - combustion ($C_xH_y + O_2 \rightarrow CO_2 + H_2O$). • Kinetics is the study of reaction rates. Several factors affect reaction rates, including temperature, concentration, surface area, and the presence of a catalyst. • Reaction rates/kinetics are affected by activation energy, catalysis, and the degree of randomness (entropy). Catalysts decrease the amount of activation energy needed. • Chemical reactions ~~based on the net heat energy~~ are exothermic reactions (heat producing) and endothermic reactions (heat absorbing). • Reactions occurring in both forward and reverse directions are	• classify types of chemical reactions as synthesis, decomposition, single replacement, double replacement, neutralization, and/or combustion. • recognize that there is a natural tendency for systems to move in a direction of randomness (entropy). • recognize equations for redox reactions and neutralization reactions. • distinguish between an endothermic and exothermic process. • interpret reaction rate diagrams. • identify and explain the effect ~~of~~ the following factors ~~that affect the rate and time~~ have on the rate of a chemical reaction: ~~(~~catalyst, temperature, concentration, size of particles~~)~~. • distinguish between irreversible reactions and those at equilibrium. • predict the shift in equilibrium when a system is subjected to a stress (Le Chatelier's Principle) and identify the factors that can cause a shift in equilibrium (temperature, pressure, and concentration.) • ~~Identify common examples of reaction types.~~

Standard CH.3

CH.3	The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include a) nomenclature; b) balancing chemical equations; c) writing chemical formulas; d) bonding types; e) reaction types; and f) reaction rates, kinetics, and equilibrium.

Essential Understandings	Essential Knowledge and Skills
reversible. Reversible reactions can reach a state of *equilibrium*, where the reaction rates of both the forward and reverse reactions are constant. ~~can occur in two directions simultaneously.~~ Le Chatelier's Principle indicates the qualitative prediction of direction of change with temperature, pressure, and concentration.	

Standard CH.4

CH.4 The student will investigate and understand that chemical quantities are based on molar relationships. Key concepts include

a) Avogadro's principle and molar volume;
b) stoichiometric relationships;
c) solution concentrations; and
d) acid/base theory; strong electrolytes, weak electrolytes, and nonelectrolytes; dissociation and ionization; pH and pOH; and the titration process.

Essential Understandings

The concepts developed in this standard include the following:

- Atoms and molecules are too small to count by usual means. A *mole* is a way of counting any type of particle (atoms, molecules, and formula units).
- Avogadro's number = 6.02×10^{23} particles per mole.
- Molar mass of a substance is its average atomic mass in grams from the Periodic Table.
- Molar volume = ~~22.4 dm^3/mole and/or~~ 22.4 L/mole for any gas at standard temperature and pressure (STP).
- Stoichiometry involves quantitative relationships. Stoichiometric relationships are based on mole quantities in a balanced equation.
- Total grams of reactant(s) = total grams of product(s).
- Molarity = ~~moles/dm^3 or~~ moles of solute/L of solution.
- [ ] refers to molar concentration.
- When solutions are diluted, the moles of solute present initially remain.
- The saturation of a solution is dependent on the amount of solute present in the solution.
- Two important classes of compounds are acids and bases. Acids and bases are defined by several theories. According to ~~T~~the Arrhenius theory ~~of~~, acids are characterized by their sour taste, low pH, and the fact that they turn litmus paper red. According to ~~T~~the Arrhenius theory ~~of~~, bases are characterized by their bitter taste, slippery feel, high pH, and the fact that they turn litmus paper blue. According to ~~T~~the

Essential Knowledge and Skills

~~Knowledge Skills~~ In order to meet this standard, it is expected that students will

- perform conversions between mass, volume, particles, and moles of a substance.
- ~~Make~~ perform stoichiometric calculations involving the following relationships:
  - mole-mole;
  - mass-mass;
  - mole-mass;
  - mass-volume;
  - mole-volume; ~~and~~
  - volume-volume;
  - ~~particle-particle;~~
  - mole-particle;
  - mass-particle; and
  - volume-particle.
- identify the limiting reactant (reagent) in a reaction.
- calculate percent yield of a reaction.
- perform calculations involving the molarity of a solution, including dilutions.
- interpret solubility curves.
- differentiate between the defining characteristics of the Arrhenius theory of acids and bases and the Bronsted-Lowry theory of acids and bases.

Standard CH.4

CH.4	The student will investigate and understand that chemical quantities are based on molar relationships. Key concepts include a) Avogadro's principle and molar volume; b) stoichiometric relationships; c) solution concentrations; and d) acid/base theory; strong electrolytes, weak electrolytes, and nonelectrolytes; dissociation and ionization; pH and pOH; and the titration process.

Essential Understandings	Essential Knowledge and Skills
Bronsted-Lowry theory ~~of~~, acids are proton donors, whereas bases are proton acceptors. Acids and bases dissociate in varying degrees. • Strong electrolytes dissociate completely. Weak electrolytes dissociate partially. Non-electrolytes do not dissociate. • pH is a number scale ranging from 0 to 14 that represents the acidity of a solution. The pH number denotes hydrogen (hydronium) ion concentration. The pOH number denotes hydroxide ion concentration. The higher the hydronium [H_3O^+] concentration, the lower the pH. • pH + pOH = 14 • Strong acid-strong base titration is the process that measures [H~~+~~$^+$] and [OH-$^-$]. • Indicators show color changes at certain pH levels.	• identify common examples of acids and bases, including vinegar and ammonia. • compare and contrast the differences between strong, weak, and non-electrolytes. • relate the hydronium ion concentration to the pH scale. • perform titrations in a laboratory setting using indicators.

Standard CH.5

CH.5	The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include a) pressure, temperature, and volume; b) partial pressure and gas laws; c) vapor pressure; d) phase changes; e) molar heats of fusion and vaporization; f) specific heat capacity; and g) colligative properties.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Atoms and molecules are in constant motion~~, and the amount of motion depends on the substance's state of matter~~. • The phase of a substance depends on temperature and pressure. • Temperature is a measurement of the average kinetic energy in a sample. There is a direct relationship between temperature and average kinetic energy. • The ~~K~~kinetic ~~M~~molecular ~~T~~theory is a model for predicting and explaining gas behavior. • Gases have mass and occupy space. Gas particles are in constant, rapid, random motion and exert pressure as they collide with the walls of their containers. Gas molecules with the lightest mass travel fastest. Relatively large distances separate gas particles from each other. • Equal volumes of gases at the same temperature and pressure contain an equal number of particles. Pressure ~~U~~units include atm, ~~K~~kPa, and mm ~~of~~ Hg. • An ~~I~~ideal ~~G~~gas does not exist, but this concept is used to model gas behavior. A ~~R~~real ~~G~~gas exists, has intermolecular forces and particle volume, and can change states. The Ideal Gas Law states that PV = nRT. • The pressure and volume of a sample of a gas at constant temperature are inversely proportional to each other (Boyle's Law: $P_1V_1 = P_2V_2$).	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • explain the behavior of gases and the relationship between pressure and volume (Boyle's Law), and volume and temperature (Charles' Law). • solve problems and interpret graphs involving the gas laws. • identify how hydrogen bonding in water plays an important role in many physical, chemical, and biological phenomena. • interpret vapor pressure graphs. • graph and interpret a heating curve (temperature vs. time). • interpret a phase diagram of water. • calculate energy changes, using molar heat of fusion and molar heat of vaporization. • calculate energy changes, using specific heat capacity. • ~~Perform calorimetry calculations.~~ • examine the polarity of various solutes and solvents in solution formation.

Standard CH.5

CH.5	The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include a) pressure, temperature, and volume; b) partial pressure and gas laws; c) vapor pressure; d) phase changes; e) molar heats of fusion and vaporization; f) specific heat capacity; and g) colligative properties.

Essential Understandings	Essential Knowledge and Skills
• At constant pressure, the volume of a fixed amount of gas is directly proportional to its absolute temperature (Charles' Law: $V_1/T_1 = V_2/T_2$). • The Combined Gas Law ($P_1V_1/T_1 = P_2V_2/T_2$) relates pressure, volume, and temperature of a gas. • The sum of the partial pressures of all the components in a gas mixture is equal to the total pressure of a gas mixture (Dalton's law of partial pressures). • Forces of attraction (intermolecular forces) between molecules determine ~~the physical changes of state~~ their state of matter at a given temperature. Forces of attraction include hydrogen bonding, dipole-dipole attraction, and London dispersion (van der Waals) forces. • Vapor pressure is ~~a property of a substance determined by intermolecular forces~~ the pressure of the vapor found directly above a liquid in a closed container. When the vapor pressure equals the atmospheric pressure, a liquid boils. Volatile liquids have high vapor pressures, weak intermolecular forces, and low boiling points. Nonvolatile liquids have low vapor pressures, strong intermolecular forces and high boiling points. • Solid, liquid, and gas phases of a substance have different energy content. Pressure, temperature, and volume changes can cause a change in physical state. Specific amounts of energy are absorbed or released during phase changes. • A fourth ~~state~~ phase of matter is ~~the~~ plasma ~~phase~~. ~~A~~ Plasma is formed	

Standard CH.5

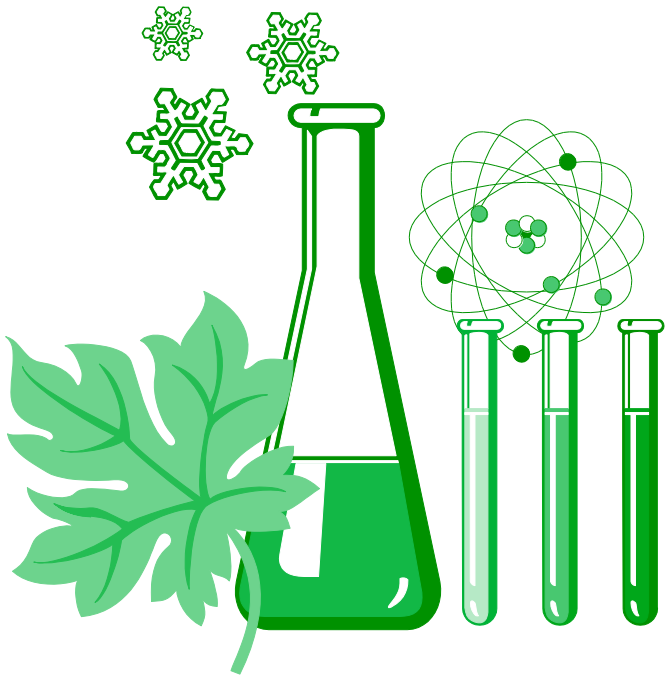
CH.5	The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include a) pressure, temperature, and volume; b) partial pressure and gas laws; c) vapor pressure; d) phase changes; e) molar heats of fusion and vaporization; f) specific heat capacity; and g) colligative properties.

Essential Understandings	Essential Knowledge and Skills
when a gas is heated to a temperature at which its electrons dissociate from the nuclei. • A heating curve graphically describes the relationship between temperature and energy (heat). It can be used to identify a substance's ~~state~~ phase of matter at a given temperature as well as the temperature(s) at which it changes ~~state~~ phase. It also shows the strength of the intermolecular forces present in a substance. • Molar heat of fusion is a property that describes the amount of energy needed to convert one mole of a substance between its solid and liquid states. Molar heat of vaporization is a property that describes the amount of energy needed to convert one mole of a substance between its liquid and gas states. Specific heat capacity is a property of a substance that tells the amount of energy needed to raise one gram of a substance by one degree Celsius. The values of these properties are related to the strength of their intermolecular forces. • Solutions can be a variety of solute/solvent combinations: gas/gas, gas/liquid, liquid/liquid, solid/liquid, gas/solid, liquid/solid, or solid/solid. • Polar substances dissolve ionic or polar substances; nonpolar substances dissolve nonpolar substances. The number of solute particles changes the freezing point and boiling point of a pure substance. • A liquid's boiling point and freezing point are affected by changes in atmospheric pressure. A liquid's boiling point and freezing point are affected by the presence of certain solutes.	

Standard CH.6

CH.6	The student will investigate and understand how basic chemical properties relate to organic chemistry and biochemistry. Key concepts include a) unique properties of carbon that allow multi-carbon compounds; and b) uses in pharmaceuticals and genetics, petrochemicals, plastics and food.

Essential Understandings	Essential Knowledge and Skills
It is expected that the content of this SOL is incorporated into the appropriate SOL as that content is being taught (i.e., bonding types, shapes, etc.) and not isolated as a discrete unit. The concepts developed in this standard include the following: • The bonding characteristics of carbon contribute to its stability and allow it to be the foundation of organic molecules. These characteristics result in the formation of a large variety of structures such as DNA, RNA and amino acids. • Carbon-based compounds include simple hydrocarbons, small carbon-containing molecules with functional groups, complex polymers, and biological molecules. • Petrochemicals contain hydrocarbons, including propane, butane, and octane. • There is a close relationship between the properties and structure of organic molecules. • Common pharmaceuticals that are organic compounds include aspirin, vitamins, and insulin. • Small molecules link to make large molecules~~,~~ called polymers~~,~~ that have combinations with repetitive subunits. Natural polymers include proteins and nucleic acids. Human-made (synthetic) polymers include polythene, nylon and Kevlar.	In order to meet this standard, it is expected that students will • describe how saturation affects shape and reactivity of carbon compounds. • draw Lewis dot structures, identify geometries, and describe polarities of the following molecules: CH_4, C_2H_6, C_2H_4, C_2H_2, CH_3CH_2OH, CH_2O, C_6H_6, CH_3COOH. • recognize that organic compounds play a role in natural and synthetic pharmaceuticals. • recognize that nucleic acids and proteins are important natural polymers. • recognize that plastics formed from petrochemicals are organic compounds that consist of long chains of carbons. • conduct a ~~synthesis~~ lab that exemplifies the versatility and importance of organic compounds (e.g., aspirin, an ester, a polymer).



Science Standards of Learning Curriculum Framework

Physics

Final Review
November 18, 2010

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Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

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

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

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

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Standard PH.1

PH.1 The student will plan and conduct investigations using experimental design and product design processes. Key concepts include

a) the components of a system are defined;
b) instruments are selected and used to extend observations and measurements;
c) information is recorded and presented in an organized format;
d) the limitations of the experimental apparatus and design are recognized;
e) the limitations of measured quantities are recognized through the appropriate use of significant figures or error ranges;
f) models and simulations are used to visualize and explain phenomena, to make predictions from hypotheses, and to interpret data; and
g) appropriate technology, including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Appropriate instruments are used to measure ~~displacement,~~ position, time, mass, force, volume, temperature, ~~heat exchange, energy transformations,~~ motion, fields, ~~and~~ electric ~~charge~~ current, and potential. • No measurement is complete without a statement about its ~~exactness~~ uncertainty. • Experimental records, including experimental diagrams, data, and procedures, are kept concurrently with experimentation. • Tables, spreadsheets, and graphs are used to interpret, organize, and clarify experimental observations, possible explanations, and models for phenomena being observed. • ~~The average for a set of data is a valid way to estimate the true value of the set.~~ • ~~The spread in a set of data is an indication of the error in the measurement: a large spread indicates a large error, and a small spread indicates a small error.~~ • ~~The difference between the accepted value and the measured value is the uncertainty or error.~~ • ~~Measurements are always recorded with appropriate SI units.~~ • ~~Calculations are made using appropriate SI units.~~	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • measure and record ~~displacement,~~ position, time, mass, force, volume, temperature, ~~heat exchange, energy transformations,~~ motion, fields, and electric ~~charge~~ current and potential, using appropriate technology. • determine ~~percent error from~~ accuracy of measurement by comparing the experimental averages and the theoretical value~~s~~. • determine precision of measurement using range or standard deviation. • follow safe practices in all laboratory procedures. • ~~calculate average values, and compare to theoretical values.~~ • use simulations to model physical phenomena. • draw conclusions and provide reasoning using supporting data.

Standard PH.1

PH.1	The student will plan and conduct investigations using experimental design and product design processes. Key concepts include a) the components of a system are defined; b) instruments are selected and used to extend observations and measurements; c) information is recorded and presented in an organized format; d) the limitations of the experimental apparatus and design are recognized; e) the limitations of measured quantities are recognized through the appropriate use of significant figures or error ranges; f) models and simulations are used to visualize and explain phenomena, to make predictions from hypotheses, and to interpret data; and g) appropriate technology, including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results.

Essential Understandings	Essential Knowledge and Skills
• <u>Accuracy is the difference between the accepted value and the measured value.</u> • <u>Precision is the spread of repeated measurements.</u> • Results of calculations or analyses of data are reported in appropriate numbers of significant digits. • Data are organized into tables and graphed when involving dependent and independent variables.	

Standard PH.2

PH.2 The student will investigate and understand how to analyze and interpret data. Key concepts include

a) a description of a physical problem is translated into a mathematical statement in order to find a solution;
b) relationships between physical quantities are determined using the shape of a curve passing through experimentally obtained data;
c) the slope of a linear relationship is calculated and includes appropriate units;
d) interpolated, extrapolated, and analyzed trends are used to make predictions; and
e) situations with vector quantities are analyzed utilizing trigonometric or graphical methods.

Essential Understandings

The concepts developed in this standard include the following:

- Mathematics is a tool used to ~~explain~~ model and describe phenomena.
- ~~Dimensional analysis is the verification of the appropriateness of the units. (This can be used as a consistency check in calculations as well as in experiments.)~~
- Graphing ~~is~~ and dimensional analysis are used to reveal relationships and other important features of data.
- Predictions are made from trends based on the data.
- The shape of the curve ~~passing through~~ fit to experimentally obtained data is used to determine the relationship of the plotted quantities.
- All experimental data do not follow a linear relationship.
- The area under the curve of experimentally obtained data is used to determine related physical quantities.
- Not all quantities add ~~algebraically~~ arithmetically. Some must be combined using trigonometry. These quantities are known as vectors.
- ~~A p~~Physical phenomena or events can often be described in mathematical terms (as an equation or inequality).

Essential Knowledge and Skills

~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will

- recognize linear and nonlinear relationships from graphed data.
- ~~draw the~~ where appropriate, draw a straight line through a set of experimental data points and determine the slope~~, using appropriate SI units~~ and/or area under the curve.
- use dimensional analysis to ~~solve problems~~ verify appropriate units.
- ~~combine vectors and resolve vectors into components, using graphical methods that place scaled vectors head-to-tail.~~
- ~~sketch a vector diagram, and trigonometrically solve for the components.~~
- ~~sketch the components of a vector, and trigonometrically solve for the resultant.~~
- combine vectors into resultants utilizing trigonometric or graphical methods.
- resolve vectors into components utilizing trigonometric or graphical methods.

Standard PH.3

PH.3 The student will investigate and demonstrate an understanding of the nature of science, scientific reasoning, and logic. Key concepts include

a) analysis of scientific sources to develop and refine research hypotheses;
b) analysis of how science explains and predicts relationships;
c) evaluation of evidence for scientific theories;
d) examination of how new discoveries result in modification of existing theories or establishment of new paradigms; and
e) construction and defense of a scientific viewpoint.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts a) the natural world is understandable; b) science is based on evidence - both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. • Experimentation may support a hypothesis, falsify it, or lead to new discoveries. • The hypothesis may be modified based upon data and analysis. • A careful study of prior reported research is a basis for the formation of a research hypothesis. • A theory is a comprehensive and effective explanation, which is well supported by experimentation and observation, of a set of phenomena. • Science is a human endeavor relying on human qualities, such as reasoning, insight, energy, skill, and creativity as well as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • identify and explain the interaction between human nature and the scientific process. • identify examples of a paradigm shift (e.g., quantum mechanics). • ~~relativity and quantum mechanics are recent examples of paradigm shifts in theoretical physics.~~ • ~~the change from an earth-centered to a sun-centered model of the solar system is an example of a paradigm shift.~~

Standard PH.4

PH.4	The student will investigate and understand how applications of physics affect the world. Key concepts include a) examples from the real world; and b) exploration of the roles and contributions of science and technology.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • ~~Physics d~~Discoveries in physics, both theoretical and experimental, have resulted in advancements in communication, medicine, engineering, transportation, commerce, exploration, and technology. • Journals, books, the Internet, and other sources are used in order to identify key contributors and their contributions to physics as well as their impact on the real world.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • be aware of real-world applications of physics, and the importance of physics in the advancement of various fields, such as medicine, engineering, technology, etc.

Standard PH.5

PH.5 The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include

a) linear motion;
b) uniform circular motion;
c) projectile motion;
d) Newton's laws of motion;
e) gravitation;
f) planetary motion; and
g) work, power, and energy.

Essential Understandings

The concepts developed in this standard include the following:

- Newton's three laws of motion are the basis for understanding the mechanical universe.
- Linear motion graphs include
  - displacement (d) vs. time (t)
  - velocity (v) vs. time (t)
  - acceleration (a) vs. time (t)
- Position, displacement, velocity, and acceleration are vector quantities.
- ~~The concept of m~~Motion is described in terms of position, displacement, time, velocity, and acceleration~~, and their dependence on time~~.
- ~~Graphical analysis is used as a representation of motion.~~
- Velocity is the change in ~~distance~~ displacement divided by the change in time. A straight-line, position-time graph indicates constant velocity. The slope of a ~~distance~~displacement-time graph is the velocity.
- Forces are interactions that can cause objects to accelerate. When one object exerts a force on a second object, the second exerts a force on the first that is equal in magnitude but opposite in direction.
- An object with no net force acting on it is stationary or moves with constant velocity.
- Acceleration is the change in velocity divided by the change in time. A

Essential Knowledge and Skills

~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will

- qualitatively explain motion in terms of Newton's Laws.
- solve problems involving force (F), mass (m), and acceleration (a).
- construct and analyze displacement (d) vs. time (t), velocity (v) vs. time (t), and acceleration (a) vs. time (t) graphs.
- solve problems involving displacement, velocity, acceleration, and time in one and two dimensions (only constant acceleration).
- resolve vector diagrams involving ~~distance~~ displacement and velocity into their components along perpendicular axes.
- draw vector diagrams of a projectile's motion. Find range, trajectory, height of the projectile, and time of flight (uniform gravitational field, no air resistance).
- distinguish between centripetal and centrifugal force.
- solve problems related to free-falling objects, including 2-D motion.
- solve problems using Newton's Law of Universal Gravitation.
- ~~solve problems using the coefficient of friction.~~
- solve problems involving multiple forces, using free-body diagrams.
- solve problems involving mechanical work, power, and energy.

Standard PH.5

PH.5	The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include a) linear motion; b) uniform circular motion; c) projectile motion; d) Newton's laws of motion; e) gravitation; f) planetary motion; and g) work, power, and energy.

Essential Understandings	Essential Knowledge and Skills
straight-line, velocity-time graph indicates constant acceleration. A horizontal-line, velocity-time graph indicates zero acceleration. The slope of a velocity-time graph is the acceleration. • The acceleration of a body is directly proportional to the net force on it and inversely proportional to its mass. • ~~Horizontal and vertical components of the motion of a projectile are independent of one another.~~ • In a uniform vertical gravitational field with negligible air resistance, ~~a projectile moves~~ horizontal and vertical components of the motion of a projectile are independent of one another with constant horizontal velocity and constant vertical acceleration. • An object moving ~~uniformly~~ along a ~~circle~~ circular path ~~moves~~ with a constant speed ~~and with~~ experiences an acceleration directed toward the center of the circle. • The force that causes an object to move in a circular path is directed centripetally, toward the center of the circle. The object's inertia is sometimes falsely characterized as a centrifugal or outward-directed force. • ~~Friction is a force that acts in a direction opposite the velocity.~~ • Weight is the gravitational force acting on a body. • Newton's Law of Universal Gravitation can be used to determine the force between objects separated by a known distance, and ~~the distance between objects with a known gravitational attraction.~~ ~~Newton's Law of~~	• describe the forces involved in circular motion. • ~~Work and energy are measured in Joules, which is a derived unit equal to a Nm or kgm^2/s^2.~~ • ~~Power is measured in Watts, which is a derived unit equal to a J/s.~~ • ~~($F_w = mg$)~~

Standard PH.5

PH.5	The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include a) linear motion; b) uniform circular motion; c) projectile motion; d) Newton's laws of motion; e) gravitation; f) planetary motion; and g) work, power, and energy.

Essential Understandings	Essential Knowledge and Skills
~~Universal Gravitation~~ describes the force that determines the motion of celestial objects. The total force on a body can be represented as a vector sum of constituent forces. • ~~Centripetal force is a "true" force acting on a body in circular motion while centrifugal force is a "false" force that describes the feeling experienced in centripetal acceleration.~~ • For a constant force acting on an object, the impulse by that force is the product of the force and the time the object experiences the force. The impulse also equals the change in momentum of the object. • ~~Energy is the capacity to do work. Work and energy are expressed in the same units, but are not identical. When work is done, energy converts from one form to another and energy is conserved. Work is change in kinetic energy.~~ Work is the mechanical transfer of energy to or from a system and is the product of a force at the point of application and the parallel component of the object's displacement. The net work on a system equals its change in velocity. • Forces within a system transform energy from one form to another with no change in the system's total energy. • For a constant force acting on an object, the work done by that force ~~Work~~ is the product of the force ~~exerted on an object~~ and the distance the object moves in the direction of the force. The net work performed on an object equals its change in kinetic energy. • Power is the rate of doing work.	

Standard PH.6

PH.6	The student will investigate and understand that quantities including mass, energy, momentum, and charge are conserved. Key concepts include a) kinetic and potential energy; b) elastic and inelastic collisions; and c) mass/energy equivalence.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Kinetic energy is the energy of motion. Potential energy is the energy due to an object's position or state. • ~~Quantities such as~~ Total energy and momentum are conserved ~~when they are exchanged or transformed, and their total quantity remains the same~~. • For elastic collisions, total momentum and total kinetic energy are conserved. For inelastic collisions, total momentum is conserved and some kinetic energy is transformed to other forms of energy~~, such as heat~~. • Electrical charge moves through electrical circuits and is conserved. • In some systems the conservation of mass and energy must take into account the principle of mass/energy equivalence.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • ~~Electric power (watt) is change in electrical energy divided by corresponding change in time. Current (ampere) is the amount of charge that moves through a circuit element divided by the elapsed time. Electric potential difference (voltage) is change in electric potential energy per unit charge.~~ • ~~In any system of electrical charge, electrical movement, or electrical interaction, both charge and energy are conserved.~~ • provide and explain examples of how energy can be converted from potential energy to kinetic energy and the reverse. • provide and explain examples showing linear momentum is the product of mass and velocity, and is conserved in a closed system.

Standard PH.7

PH.7	The student will investigate and understand that energy can be transferred and transformed to provide usable work. Key concepts include a) transfer and storage of energy among systems including mechanical, thermal, gravitational, electromagnetic, chemical, and nuclear systems; and b) efficiency of systems.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Energy can be transformed from one form to another. ~~(Example: Falling water turns a turbine that generates electricity and produces heat and light in a classroom.)~~ • Efficiency ~~of a machine~~ is the ratio of output work to input work.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • Illustrate that energy can be transformed from one form to another, using examples from everyday life and technology. • Calculate efficiency by identifying the useful energy in a process. • Qualitatively identify the various ~~forms of~~ energy transformations in simple demonstrations.

Standard PH.8

PH.8	The student will investigate and understand wave phenomena. Key concepts include a) wave characteristics; b) fundamental wave processes; and c) light and sound in terms of wave models.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Mechanical waves transport energy as a traveling disturbance in a medium. • In a transverse wave, particles of the medium ~~move~~ oscillate in a direction perpendicular to the direction the wave travels. • In a longitudinal wave, particles of the medium ~~move~~ oscillate in a direction parallel to the direction the wave travels. • ~~For harmonic waves,~~ Wave velocity equals the product of the frequency and the wavelength. • For small angles of oscillation, a pendulum exhibits simple harmonic motion. • Frequency and period are reciprocals of each other. • Waves are reflected and ~~refracted~~ transmitted when they encounter a change in medium or a boundary. • The overlapping of two or more waves results in constructive or destructive interference. • When source and observer are in relative motion, a shift in frequency occurs (Doppler effect). • Sound is a longitudinal mechanical wave that travels through matter. • Light is a transverse electromagnetic wave ~~(transverse)~~ that can travel through matter as well as a vacuum. • Reflection is the change of direction of the wave in the original medium. • Refraction is the change of direction ~~(bending)~~ of the wave ~~in the new medium~~ at the boundary between two media.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • ~~Period, wavelength, and frequency are measured in seconds, meters, and Hertz.~~ • ~~identify examples of longitudinal and transverse waves.~~ • identify examples of and differentiate between transverse and longitudinal waves, using ~~simple~~ simulations and/or models ~~(slinky, stadium waves)~~. • illustrate period, wavelength, and amplitude on a graphic representation of a ~~harmonic~~ wave. • solve problems involving frequency, period, wavelength, and velocity. • distinguish between superimposed waves that are in-phase and those that are out-of-phase. • graphically illustrate reflection and refraction of a wave when it encounters a change in medium or a boundary. • graphically illustrate constructive and destructive interference. • identify a standing wave, using a string.

Standard PH.8

PH.8	The student will investigate and understand wave phenomena. Key concepts include a) wave characteristics; b) fundamental wave processes; and c) light and sound in terms of wave models.

Essential Understandings	Essential Knowledge and Skills
• Diffraction is the spreading of a wave around a barrier or an aperture. • The pitch of a note is determined by the frequency of the sound wave. • The color of light is determined by the frequency of the light wave. • As the amplitude of a sound wave increases, the loudness of the sound increases. • As the amplitude of a light wave increases, the ~~brightness~~ intensity of the light increases. • Electromagnetic waves can be polarized by reflection or transmission. • ~~Polarizing filters can transmit one direction of polarized light and block the other.~~ Polarizing filters allow light oriented in one direction (or component of) to pass through.	

Standard PH.9

PH.9	The student will investigate and understand that different frequencies and wavelengths in the electromagnetic spectrum are phenomena ranging from radio waves through visible light to gamma radiation. Key concepts include a) the properties, behaviors, and relative size of radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays; b) wave/particle dual nature of light; and c) current applications based on the respective wavelengths.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Frequency, wavelength, and energy vary across the entire electromagnetic spectrum. • The long wavelength, low frequency portion of the electromagnetic spectrum is used for communication (e.g., radio, TV, cellular phone). • Medium wavelengths (infrared) are used for heating~~ and night-vision enhancing devices~~ and remote control devices. • Visible light comprises a ~~very~~ relatively narrow portion of the electromagnetic spectrum. • Ultraviolet (UV) wavelengths (shorter than the visible spectrum) are ionizing radiation and can cause damage to humans. UV is responsible for sunburn, and can be used for sterilization and fluorescence. • X-rays and gamma rays are the highest frequency ~~and~~ (shortest wavelength) and are used primarily for medical purposes. These wavelengths are also ionizing radiation and can cause damage to humans.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • describe the change in observed frequency of waves due to the motion of a source or a receiver (the Doppler effect). • identify common uses for radio waves, microwaves, X-rays and gamma rays.

Standard PH.10

PH.10	The student will investigate and understand how to use the field concept to describe the effects of gravitational, electric, and magnetic forces. Key concepts include a) inverse square laws (Newton's law of universal gravitation and Coulomb's law); and b) technological applications.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The electrostatic force (Coulomb's law) can be either repulsive or attractive, depending on the sign of the charges. • The gravitational force (Newton's ~~l~~Law of Gravitation) is always an attractive force. • The force found from Newton's ~~l~~Law of Gravitation and in Coulomb's law is dependent on the inverse square of the distance between two objects. • The interaction of two particles at a distance can be described as a two-step process that occur simultaneously: the creation of a field by one of the particles and the interaction of the field with the second particle. • ~~The rotation of the coil of a motor or a generator through a magnetic field is used to transfer energy.~~ • The force a magnetic field exerts on a moving electrical charge has a direction perpendicular to both the velocity and field directions. Its magnitude is dependent on the velocity of the charge, the magnitude of the charge, and the strength of the magnetic field.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • ~~Coulomb's law states that the magnitude F of the electrostatic force exerted by one point charge on another point charge is directly proportional to the magnitudes of q1 and q2 of the charges and inversely proportional to the square of the distance r between them: $F = k (q_1 q_2)/r^2$~~. • ~~Newton's Law of Universal Gravitation states that every particle in the universe attracts every other particle in the universe. $F = G (m_1 m_2)/r^2$. (F is the force, G is the universal gravitation constant, m is the mass of the two particles, and r is the distance between them.)~~ • describe the attractive or repulsive forces between objects relative to their forces and distance between them (Coulomb's Law.) • describe the attraction of particles (Newton's Law of Universal Gravitation.) • describe the effect of a uniform magnetic field on a moving electrical charge.

Standard PH.11

PH.11	The student will investigate and understand how to diagram, construct, and analyze basic electrical circuits and explain the function of various circuit components. Key concepts include a) Ohm's law; b) series, parallel, and combined circuits; c) electrical power; and d) alternating and direct currents.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Current is ~~the flow of electrical charge~~ the rate at which charge moves through a circuit element. • Electric potential difference (~~V~~voltage) in a circuit provides the energy that drives the current. • Elements in a circuit are positioned relative to other elements either in series or parallel. • According to Ohm's law, the resistance of an element equals the voltage across the element divided by the current through the element. • ~~Voltage~~ Potential difference (voltage) is the change in electrical potential energy per unit charge across that element. • The dissipated power of a circuit element equals the product of the voltage across that element and the current through that element. • In a DC (direct current) circuit, the current flows in one direction, whereas in an AC (alternating current) circuit, the current switches direction several times per second (60Hz in the U.S.).	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • recognize a series and a parallel circuit. • apply Ohm's law to a series and a parallel circuit. • assemble simple circuits composed of batteries and resistors in series and in parallel. • solve simple circuits using Ohm's law. • calculate the dissipated power of a circuit element. • recognize that DC power is supplied by batteries and that AC power is supplied by electrical wall sockets.

Standard PH.12

PH.12	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. Key concepts may include a) wave/particle duality; b) wave properties of matter; c) matter/energy equivalence; d) quantum mechanics and uncertainty; e) relativity; f) nuclear physics; g) solid state physics; h) nanotechnology; i) superconductivity; and j) radioactivity.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • For processes that are important on the atomic scale, objects exhibit both wave characteristics (e.g., interference) as well as particle characteristics (e.g., discrete amounts and a fixed definite number of electrons per atom). • Nuclear physics is the study of the interaction of the protons and neutrons in the atom's nucleus. • The nuclear force binds protons and neutrons in the nucleus. *Fission* is the breakup of heavier nuclei to lighter nuclei. *Fusion* is the combination of lighter nuclei to heavier nuclei. • ~~The dramatic~~ Dramatic examples of ~~the~~ mass-energy transformation are the fusion of hydrogen in the sun, which provides light and heat for the earth, and the fission process in nuclear reactors that provide electricity. • Natural radioactivity is the spontaneous disintegration of unstable nuclei. Alpha, beta, and gamma rays are different emissions associated with radioactive decay. • The special theory of relativity predicts that energy and matter can be converted into each other. • Objects cannot travel faster than the speed of light.	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • explain that ~~T~~the motion of objects traveling near or approaching the speed of light does not follow Newtonian mechanics but must be treated within the theory of relativity. • describe the relationship between the Big Bang theory timeline and particle physics. • describe the structure of the atomic nucleus, including quarks. • provide examples of technologies used to explore the nanoscale.

Standard PH.12

PH.12	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. Key concepts may include a) wave/particle duality; b) wave properties of matter; c) matter/energy equivalence; d) quantum mechanics and uncertainty; e) relativity; f) nuclear physics; g) solid state physics; h) nanotechnology; i) superconductivity; and j) radioactivity.

Essential Understandings	Essential Knowledge and Skills
• ~~Many substances in the natural world have a crystal structure, including most metals and minerals.~~ • ~~Atoms and molecules bind together in regular arrays to form crystals. The structure of these crystals is important in determining the properties of these materials (appearance, hardness, etc.).~~ The atoms and molecules of many substances in the natural world, including most metals and minerals, bind together in regular arrays to form crystals. The structure of these crystals is important in determining the properties of these materials (appearance, hardness, etc.). • Certain materials at very low temperatures exhibit the property of zero resistance called *superconductivity*. • Electrons ~~rotating around the nucleus of an atom~~ in orbitals can be treated as standing waves in order to model the atomic spectrum. • Quantum mechanics requires an inverse relationship between the measurable location and the measurable momentum of a particle. The more accurately one determines the position of a particle, the less accurately the momentum can be known, and vice versa. This is known as the Heisenberg uncertainty principle. • Matter behaves differently at nanometer scale (size and distance) than at macroscopic scale.	