Science Standards of Learning

for Virginia Public Schools

Board of Education
Commonwealth of Virginia

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Post Office Box 2120
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Table of Contents

Science
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Goals

The purposes of scientific investigation and discovery are to satisfy humankind's quest for knowledge and understanding and to preserve and enhance the quality of the human experience. Therefore, as a result of science instruction, students will be able to:

1. Develop and use an experimental design in scientific inquiry
2. Use the language of science to communicate understanding
3. Investigate phenomena using technology
4. Apply scientific concepts, skills, and processes to everyday experiences
5. Experience the richness and excitement of scientific discovery of the natural world through the historical and collaborative quest for knowledge and understanding
6. Make informed decisions regarding contemporary issues taking into account the following:
   - public policy and legislation
   - economic costs/benefits
   - validation from scientific data and the use of scientific reasoning and logic
   - respect for living things
   - personal responsibility
   - history of scientific discovery
7. Develop scientific dispositions and habits of mind including:
   - curiosity
   - demand for verification
   - respect for logic and rational thinking
   - consideration of premises and consequences
   - respect for historical contributions
   - attention to accuracy and precision
   - patience and persistence
8. Explore science-related careers and interests.

K-12 Safety

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

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

Teachers must be knowledgeable of the properties, use, and proper disposal of all chemicals that may be judged as hazardous prior to their use in an instructional activity. Such information is referenced through the MSDS forms (Materials Safety Data Sheets). The identified precautions involving the use of goggles, gloves, aprons, and fume hoods must be followed as prescribed.

While no comprehensive list exists to cover all situations, the following should be reviewed to avoid potential safety problems. Appropriate safety procedures should be used in the following situations:

- Observing wildlife; handling living and preserved organisms; and contact with natural hazards such as poison ivy, ticks, mushrooms, insects, spiders, and snakes

- Field activities in, near, or over bodies of water
- Handling of glass tubing, sharp objects, glassware, and labware
- Natural gas burners, bunsen burners, and other sources of flame/heat
- Hazards associated with direct sunlight (sunburn and eye damage)
- Use of extreme temperatures and cryogenic materials
- Hazardous chemicals including toxins, carcinogens, flammable and explosive materials
- Acid/base neutralization reactions/dilutions
- Production of toxic gases or situations where high pressures are generated
- Biological cultures, their appropriate disposal, and recombinant DNA
- Power equipment/motors
- High voltage/exposed wiring
- Laser beam, UV, and other radiation.

The use of human body fluids or tissues is generally prohibited for classroom lab activities. Further guidance from the following sources may be taken into account:

- OSHA (Occupational Safety and Health Administration)
- ISEF (International Science and Engineering Fair Rules)
- Public health departments and local school division protocols.

The Role of Instructional Technology in Science Education

The use of current and emerging technologies is essential to the K-12 science instructional program.

Specifically, technology must

- Assist in improving every student's functional literacy. This includes improved communication through reading/information retrieval (the use of telecommunications), writing (word processing), organization and analysis of data (databases, spreadsheets, and graphics programs), selling one's idea (presentation software), and resource management (project management software).
- Be readily available and used regularly as an integral and ongoing part in the delivery and assessment of instruction.
- Include instrumentation oriented toward the instruction and learning of science concepts, skills, and processes. Technology, however, should not be limited to traditional instruments of science such as microscopes, labware, and data-collecting apparatus but should also include computers, robotics, interactive-optical laser discs, video-microscopes, graphing calculators, CD-ROMs, probeware, on-line telecommunication, software and appropriate hardware, as well as other emerging technologies.
- Be reflected in the "instructional strategies" generally developed at the local school division level.

In most cases, the application of technology in science should remain "transparent" unless it is the actual focus of the instruction. One must expect students to "do as a scientist does" and not simply hear about science if they are truly expected to explore, explain, and apply scientific concepts, skills, and processes.

As computer/technology skills are essential components of every student's education, it is important that these skills are a shared responsibility of teachers of all disciplines and grade levels. Please note the computer/technology standards following the grade five and the physical science standards respectively.

Investigate and Understand

Many of the standards in the Science Standards of Learning begin with the phrase "Students will investigate and understand." This phrase was chosen to communicate the range of **rigorous science skills** and **knowledge** levels embedded in each standard. Limiting a standard to one observable behavior such as "describe" or "explain" would have narrowed the interpretation of what was intended to be a rich, highly rigorous, and inclusive content standard.

"Investigate" refers to scientific methodology and implies systematic use of the following inquiry skills:

- Observing
- Classifying and sequencing
- Communicating
- Measuring
- Predicting
- Hypothesizing
- Inferring
- Defining, controlling, and manipulating variables in experimentation

- Designing, constructing, and interpreting models
- Interpreting, analyzing, and evaluating data.

"Understand" refers to various levels of knowledge application. In the Science Standards of Learning these knowledge levels include the ability to

- **Recall** or **recognize** important information, key definitions, terminology, and facts
- **Explain** the information in one's own words, comprehend how the information is related to other key facts, and suggest additional interpretations of its meaning or importance
- **Apply** the facts and principles to new problems or situations, recognizing what information is required for a particular situation, explaining new phenomena with the information, and determining when there are exceptions
- **Analyze** the underlying details of important facts and principles, recognizing the key relations and patterns that are not always readily visible
- **Arrange** and **combine** important information, facts, and principles to produce a new idea, plan, procedure, or product
- **Make judgments** about information in terms of accuracy, precision, consistency, or effectiveness.

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

Kindergarten

The kindergarten standards stress the use of basic science skills to explore common materials, objects, and living things. Emphasis is placed on using the senses to gather information. Students are expected to develop skills in posing simple questions, measuring, sorting, classifying, and communicating information about the natural world. The science skills are an important focus as students learn about life processes and properties of familiar materials such as magnets and water. Through phenomena including shadows, patterns of weather, and plant growth, students are introduced to the concept of change. The significance of natural resources and conservation is introduced in the kindergarten standards.

Scientific Investigation, Reasoning, and Logic

K.1 The student will conduct investigations in which

- basic properties of objects are identified by direct observation;
- observations are made from multiple positions to achieve different perspectives;
- a set of objects is sequenced according to size;
- a set of objects is separated into two groups based on a single physical attribute;
- picture graphs are constructed using 10 or fewer units;
- nonstandard units are used to measure common objects;
- an unseen member in a sequence of objects is predicted;
- a question is developed from one or more observations;
- objects are described both pictorially and verbally; and
- unusual or unexpected results in an activity are recognized.

K.2 The student will investigate and understand that humans have senses including sight, smell, hearing, touch, and taste. Senses allow one to seek, find, take in, and react or respond to information in order to learn about one's surroundings. Key concepts include

- five senses (taste, touch, smell, hearing, and sight);
- sensing organs associated with each of the senses (eyes, ears, nose, tongue, and skin); and
- sensory descriptors (sweet, sour, bitter, salty, rough, smooth, hard, soft, cold, warm, hot, loud, soft, high, low, bright, dull).

Force, Motion, and Energy

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

- attraction/nonattraction, push/pull, attract/repel, and metal/nonmetal; and
- useful applications (refrigerator magnet, can opener, magnetized screwdriver).

Matter

K.4 The student will investigate and understand that objects can be described in terms of their physical properties. Key concepts include

- the eight basic colors;
- shapes (circle, triangle, square) and forms (flexible, stiff, straight, curved);
- textures and feel (rough, smooth, hard, soft);
- relative size and weight (big, little, large, small, heavy, light, wide, thin, long, short); and
- position and speed (over, under, in, out, above, below, left, right, fast, slow).

K.5 The student will investigate and understand that water has properties that can be observed and tested. Key concepts include

- water occurs in different forms (solid, liquid, gas);
- the natural flow of water is downhill; and
- some materials float in water while others sink.

Life Processes

K.6 The student will investigate and understand basic needs and life processes of plants and animals. Key concepts include

- living things change as they grow and need food, water, and air to survive;
- plants and animals live and die (go through a life cycle); and
- offspring of plants and animals are similar but not identical to their parents and one another.

Interrelationships in Earth/Space Systems

K.7 The student will investigate and understand that shadows occur when light is blocked by an object. Key concepts include

- shadows occur in nature when sunlight is blocked by an object; and
- shadows can be produced by blocking artificial light sources.

Earth Patterns, Cycles, and Change

K.8 The student will investigate and understand simple patterns in his/her daily life. Key concepts include

- weather observations;
- the shapes and forms of many common natural objects including seeds, cones, and leaves;
- animal and plant growth; and
- home and school routines.

K.9 The student will investigate and understand that change occurs over time, and rates may be fast or slow. Key concepts include

- natural and human-made things may change over time; and
- changes can be noted and measured.

Resources

K.10 The student will investigate and understand that materials can be reused, recycled, and conserved. Key concepts include

- identifying materials and objects that can be used over and over again;
- describing everyday materials that can be recycled; and
- explaining how to conserve water and energy at home and in school.

Grade One

The first-grade standards continue to stress basic science skills in understanding familiar objects and events. Students are expected to begin conducting simple experiments and be responsible for some of the planning. Students are introduced to the concept of classifying plants and animals based on simple characteristics. Emphasis is placed on the relationships among objects and their interactions with one another. Students are expected to know the

basic relationships between the sun and Earth and between seasonal changes and plant and animal activities. Students also will begin to develop an understanding of moving objects, simple solutions, and important natural resources.

Scientific Investigation, Reasoning, and Logic

1.1 The student will plan and conduct investigations in which

- differences in physical properties are observed using the senses and simple instruments to enhance observations (magnifying glass);
- objects or events are classified and arranged according to attributes or properties;
- observations and data are communicated orally and with simple graphs, pictures, written statements, and numbers;
- length, mass, and volume are measured using standard and nonstandard units;
- inferences are made and conclusions are drawn about familiar objects and events;
- predictions are based on patterns of observation rather than random guesses; and
- simple experiments are conducted to answer questions.

Force, Motion, and Energy

1.2 The student will investigate and understand that moving objects exhibit different kinds of motion. Key concepts include

- objects may have straight, circular, and back and forth motions;
- objects vibrate;
- pushes or pulls can change the movement of an object; and
- the motion of objects may be observed in toys and in playground activities.

Matter

1.3 The student will investigate and understand how different common materials interact with water. Key concepts include

- some common liquids (vinegar) mix with water, others (oil) will not;
- some everyday solids (baking soda, powdered drink mix, sugar, salt) will dissolve, others (sand, soil, rocks) will not; and
- some substances will dissolve easily in hot water rather than cold water.

Life Processes

1.4 The student will investigate and understand that plants have life needs and functional parts and can be classified according to certain characteristics. Key concepts include

- needs (food, air, water, light, and a place to grow);
- parts (seeds, roots, stems, leaves, blossom, fruit); and
- characteristics: edible/nonedible, flowering/nonflowering, evergreen/deciduous.

1.5 The student will investigate and understand that animals, including people, have life needs and specific physical characteristics and can be classified according to certain characteristics. Key concepts include

- life needs (air, food, water, and a suitable place to live);
- physical characteristics (body coverings, body shape, appendages, and methods of movement); and
- characteristics (wild/tame, water homes/land homes).

Interrelationships in Earth/Space Systems

1.6 The student will investigate and understand the basic relationships between the sun and the Earth. Key concepts include

- the sun is the source of heat and light that warms the land, air, and water; and
- night and day are caused by the rotation of the Earth.

Earth Patterns, Cycles, and Change

1.7 The student will investigate and understand the relationship of seasonal change and weather to the activities and life processes of plants and animals. Key concepts include how temperature, light, and precipitation bring about changes in

- plants (growth, budding, falling leaves, wilting);
- animals (behaviors, hibernation, migration, body covering, habitat); and
- people (dress, recreation, work).

Resources

1.8 The student will investigate and understand that natural resources are limited. Key concepts include

- identification of natural resources (plants and animals, water, air, land, minerals, forests, and soil);
- factors that affect air and water quality;

- recycling, reusing, and reducing consumption of natural resources; and
- use of land as parks and recreational facilities.

Grade Two

The second-grade standards continue to focus on using a broad range of science skills in understanding the natural world. Making detailed observations, drawing conclusions, and recognizing unusual or unexpected data are skills needed to be able to use and validate information. Measurement in both English and metric units is stressed. The idea of living systems is introduced through habitats and the interdependence of living and nonliving things. The concept of change is explored in states of matter, life cycles, weather patterns, and seasonal effects on plants and animals.

Scientific Investigation, Reasoning, and Logic

2.1 The student will plan and conduct investigations in which

- observations are repeated to improve accuracy;
- two or more attributes are used to classify items;
- pictures and bar graphs are constructed using numbered axes;
- linear, volume, mass, and temperature measurements are made in metric (centimeters, meters, liters, degrees Celsius, grams, kilograms) and standard English units (inches, feet, yards, pints, quarts, gallons, degrees Fahrenheit, ounces, pounds);
- observation is differentiated from personal interpretation, and conclusions are drawn based on observations;
- simple physical models are constructed;
- conditions that influence a change are defined; and
- unexpected or unusual quantitative data are recognized.

Force, Motion, and Energy

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

- magnetism, iron, magnetic/nonmagnetic, opposites, poles, attract/repel; and
- important applications including the magnetic compass.

Matter

2.3 The student will investigate and understand basic properties of solids, liquids, and gases. Key concepts include

- mass and volume; and
- processes involved with changes in matter from one state to another (condensation, evaporation, melting, freezing, expanding, and contracting).

Life Processes

2.4 The student will investigate and understand that plants and animals go through a series of orderly changes in their life cycles. Key concepts include

- some animals (frogs and butterflies) go through distinct stages during their lives while others generally resemble their parents; and
- flowering plants undergo many changes from the formation of the flower to the development of the fruit.

Living Systems

2.5 The student will investigate and understand that living things are part of a system. Key concepts include

- living organisms are interdependent with their living and nonliving surroundings; and
- habitats change over time due to many influences.

Interrelationships in Earth/Space Systems

2.6 The student will investigate and understand basic types and patterns of weather. Key concepts include

- temperature, wind, condensation, precipitation, drought, flood, and storms; and
- the uses and importance of measuring and recording weather data.

Earth Patterns, Cycles, and Change

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

- effects on growth and behavior of living things (migration, estivation, hibernation, camouflage, adaptation, dormancy); and
- weathering and erosion of the land surface.

Resources

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

- important plant products (fiber, cotton, oil, spices, lumber, rubber, medicines, and paper);
- the availability of plant products affects the development of a geographic area; and
- plants provide homes and food for many animals and prevent soil from washing away.

Grade Three

The third-grade standards place increasing emphasis on conducting investigations. Students are expected to be able to develop questions, formulate simple hypotheses, make predictions, gather data, and use the metric system with greater precision. Using information to make inferences and draw conclusions becomes more important. In the area of physical science, the standards focus on simple machines, energy, and a basic understanding of matter. Behavioral and physical adaptations are examined in relation to the life needs of animals. The notion of living systems is further explored in aquatic and terrestrial food chains and diversity in environments. Patterns in the natural world are demonstrated in terms of the phases of the moon, tides, seasonal changes, the water cycle, and animal life cycles. Geological concepts are introduced through the investigation of the components of soil.

Scientific Investigation, Reasoning, and Logic

3.1 The student will plan and conduct investigations in which

- questions are developed to formulate hypotheses;
- predictions and observations are made;
- data are gathered, charted, and graphed;
- objects with similar characteristics are classified into at least two sets and two subsets;
- inferences are made and conclusions are drawn;
- natural events are sequenced chronologically;
- length is measured to the nearest centimeter;
- mass is measured to the nearest gram;
- volume is measured to the nearest milliliter and liter;
- temperature is measured to the nearest degree Celsius; and
- time is measured to the nearest minute.

Force, Motion, and Energy

3.2 The student will investigate and understand simple machines and their uses. Key concepts include

- types of simple machines (lever, screw, pulley, wheel and axle, inclined plane, and wedge);
- how simple machines function; and
- examples of simple machines found in the school, home, and work environment.

Matter

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

- objects are made of smaller parts;
- materials are composed of parts that are too small to be seen without magnification; and
- physical properties remain the same as the material is reduced in size.

Life Processes

3.4 The student will investigate and understand that behavioral and physical adaptations allow animals to respond to life needs. Key concepts include

- methods of gathering and storing food, finding shelter, defending themselves, and rearing young; and
- hibernation, migration, camouflage, mimicry, instinct, and learned behavior.

Living Systems

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

3.6 The student will investigate and understand that environments support a diversity of plants and animals that share limited resources. Key concepts include
- water-related environments (pond, marshland, swamp, stream, river, and ocean environments);
- dry-land environments (desert, grassland, rainforest, and forest environments); and
- population and community.

Interrelationships in Earth/Space Systems

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

Earth Patterns, Cycles, and Change

3.8 The student will investigate and understand basic sequences and cycles occurring in nature. Key concepts include
- sequences of natural events (day and night, seasonal changes, phases of the moon, and tides); and
- animal and plant life cycles.

3.9 The student will investigate and understand the water cycle and its relationship to life on Earth. Key concepts include
- the origin of energy that drives the water cycle;
- processes involved in the water cycle (evaporation, condensation, precipitation); and
- water supply and water conservation.

Resources

3.10 The student will investigate and understand that natural events and human influences can affect the survival of species. Key concepts include
- the interdependency of plants and animals;
- human effects on the quality of air, water, and habitat;
- the effects of fire, flood, disease, erosion, earthquake, and volcanic eruption on organisms; and
- conservation, resource renewal, habitat management, and species monitoring.

3.11 The student will investigate and understand different sources of energy. Key concepts include
- the sun's ability to produce light and heat energy;
- natural forms of energy (sunlight, water, wind);
- fossil fuels (coal, oil, natural gas) and wood;
- electricity, nuclear power; and
- renewable and nonrenewable resources.

Grade Four

The fourth-grade standards stress the importance of using information, analyzing data, and validating experimental results. Defining variables in experimentation is emphasized, and making simple predictions from picture, bar, and line graphs is underscored. Questioning and hypothesizing become more detailed at this level. Students are introduced to basic principles of electricity and to the concept of energy as it relates to work and machines. Relationships are investigated in the interactions among the Earth, moon, and sun and among plants and animals and their environments. In examining weather phenomena and conditions, students identify various factors, make predictions based on data, and evaluate the results. The importance of natural resources in Virginia is emphasized.

Scientific Investigation, Reasoning, and Logic

4.1 The student will plan and conduct investigations in which

- distinctions are made among observations, conclusions (inferences), and predictions;
- data are classified to create frequency distributions;
- appropriate metric measures are used to collect, record, and report data;
- appropriate instruments are selected to measure linear distance, volume, mass, and temperature;
- predictions are made based on data from picture graphs, bar graphs, and basic line graphs;
- hypotheses are formulated based on cause and effect relationships;
- variables that must be held constant in an experimental situation are defined; and
- numerical data that are contradictory or unusual in experimental results are recognized.

Force, Motion, and Energy

4.2 The student will investigate and understand that energy is needed to do work and that machines make work easier. Key concepts include

- energy forms (electrical, mechanical, and chemical energy);
- potential and kinetic energy;
- simple and complex machines; and
- efficiency, friction, and inertia.

4.3 The student will investigate and understand the characteristics of electricity. Key concepts include

- the nature of electricity (voltage, ampere, resistance, conductors, and insulators);
- circuits (open/closed, parallel/series);
- magnetism and magnetic fields;
- static electricity ; and
- historical contributions in understanding electricity.

Life Processes

4.4 The student will investigate and understand basic plant anatomy and life processes. Key concepts include

- the structures of typical plants (leaves, stems, roots, and flowers);
- processes and structures involved with reproduction (pollination, stamen, pistil, sepal, embryo, spore, and seed);
- photosynthesis (chlorophyll, carbon dioxide); and
- dormancy.

Living Systems

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

- behavioral and structural adaptations;
- organization of communities;
- flow of energy through food webs;
- habitats and niches;
- life cycles; and
- influence of human activity on ecosystems.

Interrelationships in Earth/Space Systems

4.6 The student will investigate and understand how weather conditions and phenomena occur and can be predicted. Key concepts include

- weather factors (temperature, air pressure, fronts, formation and type of clouds, and storms); and
- meteorological tools (barometer, hygrometer, anemometer, rain gauge, and thermometer).

Earth Patterns, Cycles, and Change

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

- the motions of the Earth, moon, and sun (revolution and rotation);
- the causes for the Earth's seasons and phases of the moon;
- the relative size, position, and makeup of the Earth, moon, and sun;
- unique properties of the Earth as a planet and as part of the solar system; and
- historical contributions in understanding the Earth-moon-sun system.

Resources

4.8 The student will investigate and understand important Virginia natural resources. Key concepts include

- watershed and water resources;
- animals and plants, both domesticated and wild;
- minerals, rocks, ores, and energy sources; and
- forests, soil, and land.

Grade Five

The fifth-grade standards emphasize the importance of selecting appropriate instruments for measuring and recording observations. The organization, analysis, and application of data continue to be an important focus of classroom inquiry. Science skills from preceding grades, including questioning, using and validating evidence, and systematic experimentation, are reinforced at this level. Students are introduced to more detailed concepts of sound and light and the tools used for studying them. Key concepts of matter include atoms, molecules, elements, and compounds, and the properties of matter are defined in greater detail. The cellular makeup of organisms and the distinguishing characteristics of groups of organisms are stressed. Students will learn about the characteristics of the oceans and the Earth's changing surface.

Scientific Investigation, Reasoning, and Logic

5.1 The student will plan and conduct investigations in which
- appropriate instruments are selected and used for making quantitative observations of length, mass, volume, and elapsed time;
- rocks, minerals, and organisms are identified using a classification key;
- data are collected, recorded, and reported using the appropriate graphical representation (graphs, charts, diagrams);
- accurate measurements are made using basic tools (thermometer, meter stick, balance, graduated cylinder);
- predictions are made using patterns, and simple graphical data are extrapolated; and
- estimations of length, mass, and volume are made.

Force, Motion, and Energy

5.2 The student will investigate and understand how sound is transmitted and is used as a means of communication. Key concepts include
- frequency, waves, wavelength, resonance, vibration;
- the ability of different media (solids, liquids, gases) to transmit sound; and
- communication tools (voice, Morse code, sonar, animal sounds, musical instruments).

5.3 The student will investigate and understand basic characteristics of white light. Key concepts include
- the visible spectrum, light waves, reflection, refraction, diffraction, opaque, transparent, translucent;
- optical tools (eyeglasses, lenses, flashlight, camera, kaleidoscope, binoculars, microscope, light boxes, telescope, prism, spectroscope, mirrors); and
- historical contributions in understanding light.

Matter

5.4 The student will investigate and understand that matter is anything that has mass; takes up space; and occurs as a solid, liquid, or gas. Key concepts include
- atoms, molecules, elements, and compounds;
- mixtures and solutions; and
- effect of temperature on the states of matter.

Living Systems

5.5 The student will investigate and understand that organisms are made of cells and have distinguishing characteristics. Key concepts include
- parts of a cell;
- five kingdoms of living things;
- vascular and nonvascular plants; and
- vertebrates and invertebrates.

Interrelationships in Earth/Space Systems

5.6 The student will investigate and understand characteristics of the ocean environment. Key concepts include
- geological characteristics (continental shelf, slope, rise);
- physical characteristics (depth, salinity, major currents);
- biological characteristics (ecosystems); and
- public policy decisions related to the ocean environment (assessment of marine organism populations, pollution prevention).

Earth Patterns, Cycles, and Change

5.7 The student will investigate and understand how the Earth's surface is constantly changing. Key concepts include
- the rock cycle including the identification of rock types;
- Earth history and fossil evidence;

- the basic structure of the Earth's interior;
- plate tectonics (earthquakes and volcanoes);
- weathering and erosion; and
- human impact.

Computer/Technology Standards by the End of Grade Five

Computer/Technology skills are essential components of every student's education. In order to maximize opportunities for students to acquire necessary skills for academic success, the teaching of these skills should be the shared responsibility of teachers of all disciplines.

Minimum skills that students should acquire by the end of **Grade 5** include the following:

C/T5.1 The student will demonstrate a basic understanding of computer theory including bits, bytes, and binary logic.

C/T5.2 The student will develop basic technology skills.
- Develop a basic technology vocabulary that includes cursor, software, memory, disk drive, hard drive, and CD-ROM.
- Select and use technology appropriate to tasks.
- Develop basic keyboarding skills.
- Operate peripheral devices.
- Apply technologies to strategies for problem solving and critical thinking.

C/T5.3 The student will process, store, retrieve, and transmit electronic information.
- Use search strategies to retrieve electronic information using databases, CD-ROMs, videodiscs, and telecommunications.
- Use electronic encyclopedias, almanacs, indexes, and catalogs.
- Use local and wide-area networks and modem-delivered services to access information from electronic databases.
- Describe advantages and disadvantages of various computer processing, storage, retrieval, and transmission techniques.

C/T5.4 The student will communicate through application software.
- Create a 1-2 page document using word processing skills, writing process steps, and publishing programs.
- Use simple computer graphics and integrate graphics into word-processed documents.
- Create simple databases and spreadsheets to manage information and create reports.
- Use local and worldwide network communication systems.

Grade Six

The sixth-grade standards continue to emphasize data analysis and experimentation. Methods are studied for testing the validity of predictions and conclusions. Scientific methodology, focusing on precision in stating hypotheses and defining dependent and independent variables, is strongly reinforced. The concept of change is explored through the study of transformations of energy and matter, both in living things and in the physical sciences. A more detailed understanding of the solar system becomes a focus of instruction. Natural resource management and its relation to public policy and cost/benefit tradeoffs are introduced.

Scientific Investigation, Reasoning, and Logic

6.1 The student will plan and conduct investigations in which
- observations are made involving fine discrimination between similar objects and organisms;
- a classification system is developed based on multiple attributes;
- differences in descriptions and working definitions are made;
- precise and approximate measures are recorded;
- scale models are used to estimate distance, volume, and quantity;
- hypotheses are stated in ways that identify the independent (manipulated) and dependent (responding) variables;
- a method is devised to test the validity of predictions and inferences;
- one variable is manipulated over time with many repeated trials;
- data are collected, recorded, analyzed, and reported using appropriate metric measurement;
- data are organized and communicated through graphical representation (graphs, charts, and diagrams); and
- models are designed to explain a sequence.

6.2 The student will demonstrate scientific reasoning and logic. Key concepts include
- ideas are investigated by asking for and actively seeking information;
- multiple tests of ideas are performed before accepting or rejecting them;
- alternative scientific explanations are analyzed; and
- conclusions are based on scientific evidence obtained from a variety of sources.

Force, Motion, and Energy

6.3 The student will investigate and understand sources of energy and their transformations. Key concepts include
- potential and kinetic energy;
- energy sources (fossil fuels, wood, wind, water, solar, and nuclear power); and
- energy transformations (mechanical to electrical, electrical to heat/light, chemical to light, and chemical to electrical/light).

6.4 The student will investigate and understand basic characteristics of electricity. Key concepts include
- electrical energy can be produced from a variety of energy sources and can be transformed into almost any other form of energy;
- electricity is related to magnetism;
- currents are either alternating or direct;
- circuits can be parallel or series;
- electrical energy can be described in volts and amps; and
- electrical energy consumption is measured using common units (kilowatts/kilowatt hours).

Matter

6.5 The student will investigate and understand that all matter is made up of atoms. Key concepts include
- atoms are made up of electrons, protons, and neutrons;
- atoms of any element are alike but are different from atoms of other elements; and
- historical development and significance of discoveries related to the atom.

6.6 The student will investigate and understand how to classify materials as elements, compounds, or mixtures. Key concepts include
- mixtures can be separated by physical processes;
- compounds can only be separated by chemical processes; and
- elements cannot be separated by physical or chemical means.

6.7 The student will investigate and understand that matter has physical and chemical properties and can undergo change. Key concepts include
- physical changes; and
- changes in chemical composition, including oxidation reactions (rusting and burning), photosynthesis, and acid-base neutralization reactions.

Life Processes

6.8 The student will investigate and understand that organisms perform life processes that are essential for the survival and perpetuation of the species. Key concepts include
- energy transformation (from food or photosynthesis); and
- respiration, movement, waste removal, growth, irritability (response), and reproduction.

Living Systems

6.9 The student will investigate and understand that organisms depend on other organisms and the nonliving components of the environment. Key concepts include
- producers, consumers, and decomposers;

- food webs and food pyramids; and
- cycles (water, carbon dioxide/oxygen, nitrogen).

Interrelationships in Earth/Space Systems

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

- the, sun, moon, Earth, other planets and their moons, meteors, asteroids, and comets;
- relative size of and distance between planets;
- the role of gravity;
- revolution and rotation;
- the mechanics of day and night and phases of the moon;
- the relationship of the Earth's tilt and seasons;
- the cause of tides; and
- the history and technology of space exploration.

Resources

6.11 The student will investigate and understand public policy decisions relating to the environment. Key concepts include

- management of renewable resources (water, air, plant life, animal life);
- management of nonrenewable resources (coal, oil, natural gas, nuclear power); and
- cost/benefit tradeoffs in conservation policies.

Life Science

The Life Science standards emphasize a more complex understanding of change, cycles, patterns, and relationships in the living world. Students build on basic principles related to these concepts by exploring the cellular organization and the classification of organisms; the dynamic relationships among organisms, populations, communities and ecosystems; and change as a result of the transmission of genetic information from generation to generation. Inquiry skills at this level include organization and mathematical analysis of data, manipulating variables in experimentation, and identifying sources of experimental error.

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

- data are organized into tables showing repeated trials and means;
- variables are defined;
- SI (metric) units are used;
- criteria are established for evaluating a prediction;
- models are constructed to illustrate and explain phenomena;
- sources of experimental error are identified;
- dependent variables, independent variables, and constants are identified;
- variables are controlled to test hypotheses and trials are repeated;
- continuous line graphs are constructed, interpreted, and used to make predictions; and
- interpretations from the same set of data are evaluated and defended.

LS.2 The student will investigate and understand that all living things are composed of cells. Key concepts include

- cell structure and organelles (cell membrane, cell wall, cytoplasm, vacuole, mitochondrion, endoplasmic reticulum, nucleus and chloroplast);
- similarities and differences between plant and animal cells;
- development of cell theory; and
- cell division (mitosis and meiosis).

LS.3 The student will investigate and understand that living things show patterns of cellular organization. Key concepts include

- cells, tissues, organs, and systems; and
- functions and processes of cells, tissues, organs, and systems (respiration, removal of wastes, growth, reproduction, digestion, and cellular transport).

LS.4 The student will investigate and understand that the basic needs of organisms must be met in order to carry out life processes. Key concepts include
- plant needs (light and energy sources, water, gases, nutrients);
- animal needs (food, water, gases, shelter, space); and
- factors that influence life processes.

LS.5 The student will investigate and understand classification of organisms. Key concepts include
- differences in number, color, size, shape, and texture of external and internal structures; and
- variation in method of locomotion, obtaining nourishment, and reproduction.

LS.6 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
- energy transfer between sunlight and chlorophyll;
- transformation of water and carbon dioxide into sugar, water, and oxygen; and
- photosynthesis as the foundation of food webs.

LS.7 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
- interactions resulting in a flow of energy and matter throughout the system;
- complex relationships in terrestrial, freshwater, and marine ecosystems; and
- energy flow in food chains, food webs, and food pyramids.

LS.8 The student will investigate and understand that interactions exist among members of a population. Key concepts include
- competition, cooperation, social hierarchy, territorial imperative; and
- influence of behavior on population interactions.

LS.9 The student will investigate and understand interactions among populations in a biological community. Key concepts include
- the relationship among producers, consumers, and decomposers in food chains and food webs;
- the relationship of predators and prey;
- competition and cooperation;
- symbiotic relationships and niches; and
- the role of parasites and their hosts.

LS.10 The student will investigate and understand how organisms adapt to biotic and abiotic factors in a biome. Key concepts include
- differences between ecosystems and biomes;
- characteristics of land, marine, and freshwater biomes; and
- adaptations that enable organisms to survive within a specific biome.

LS.11 The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic and change over time (daily, seasonal, and long term). Key concepts include
- phototropism, hibernation, and dormancy;
- factors that increase or decrease population size; and
- eutrophication, climate change, and catastrophic disturbances.

LS.12 The student will investigate and understand the relationships between ecosystem dynamics and human activity. Key concepts include
- food production and harvest;
- change in habitat size, quality, and structure;
- change in species competition;
- population disturbances and factors that threaten and enhance species survival; and
- environmental issues (water supply, air quality, energy production, and waste management).

LS.13 The student will investigate and understand that organisms reproduce and transmit genetic information to new generations. Key concepts include
- the role of DNA;
- characteristics that can and cannot be inherited;
- genetic engineering and its applications; and
- historical contributions and significance of discoveries related to genetics.

LS.14 The student will investigate and understand that organisms change over time. Key concepts include
- the relationships of mutation, adaptation, natural selection, and extinction;
- evidence of evolution of different species in the fossil record; and
- how environmental influences, as well as genetic variation, can lead to diversity of organisms.

Physical Science

The Physical Science standards continue to build on skills of systematic investigation with a clear focus on variables and repeated trials. Validating conclusions using evidence and data becomes increasingly important at this level. Students will plan and conduct research involving both classroom experimentation and literature reviews from written and electronic resources. Research methods and skills highlight practical problems and questions. Students will share their work using written reports and other presentations.

The Physical Science standards stress a more in-depth understanding of the nature and structure of matter and the characteristics of energy. The standards place considerable emphasis on the technological application of physical science principles. Major areas covered by the standards include the periodic table; physical and chemical changes; nuclear reactions; temperature and heat; sound; light; electricity and magnetism; and work, force, and motion.

PS.1 The student will plan and conduct investigations in which
- length, mass, volume, density, temperature, weight, and force are accurately measured and reported using the International System of Units (SI - metric);
- triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and spring scales are used to gather data;
- data from experiments are recorded and interpreted from bar, line, and circle graphs;
- research skills are utilized using a variety of resources;
- independent and dependent variables, constants, controls, and repeated trials are identified;
- valid conclusions are made after analyzing data;
- research methods are used to investigate practical problems and questions; and
- experimental results are presented in appropriate written form.

PS.2 The student will investigate and understand the basic nature of matter. Key concepts include
- the particle theory of matter;
- elements, compounds, mixtures, acids, bases, salts, organic, inorganic, solids, liquids, and gases;
- characteristics of types of matter based on physical and chemical properties;
- physical properties (shape, density, solubility, odor, melting point, boiling point, color); and
- chemical properties (acidity, basicity, combustibility, reactivity).

PS.3 The student will investigate and understand various models of atomic structure including Bohr and Cloud (quantum) models.

PS.4 The student will investigate and understand how to use the periodic table of elements to obtain information. Key concepts include
- symbols, atomic numbers, atomic mass, chemical families, periods, valence numbers, metals, metalloids, and nonmetals; and
- binary compounds (chemical activity, physical properties, formulas, and nature of bonding).

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
- physical changes (effect of temperature on state, particle size on solubility, and temperature on solubility);
- nuclear reactions (products of fusion and fission and their effects on human beings and the environment); and
- chemical changes (types of reactions, reactants and products, and balanced equations).

PS.6 The student will investigate and understand states and forms of energy and how energy is transferred and transformed. Key concepts include
- potential and kinetic energy;
- mechanical, chemical, and electrical energy; and
- heat, light, and sound.

PS.7 The student will investigate and understand temperature scales, heat, and heat transfer. Key concepts include
- absolute zero, phase change, freezing point, melting point, boiling point, conduction, convection, radiation, vaporization, and condensation; and
- applications of heat transfer (heat engines, thermostats, and refrigeration).

PS.8 The student will investigate and understand characteristics of sound and technological applications of sound waves. Key concepts include
- wave length, frequency, amplitude, interference; and
- technological applications of sound.

PS.9 The student will investigate and understand the nature and technological applications of light. Key concepts include
- reflection, refraction, particle theory, wave theory; and
- electromagnetic spectrum.

PS.10 The student will investigate and understand scientific principles and technological applications of work, force, and motion. Key concepts include
- work, force, mechanical advantage, efficiency, power, horsepower, gravitational force, speed/velocity, mass/weight, Newton's three laws of motion, acceleration; and
- applications (simple machines, compound machines, powered vehicles, rockets, restraining devices, projectiles).

PS.11 The student will investigate and understand basic principles of electricity and magnetism. Key concepts include
- static, current, circuits; and
- magnetic fields and electromagnets.

Computer/Technology Standards by the End of Grade Eight

Computer/Technology skills are essential components of every student's education. In order to maximize opportunities for students to acquire necessary skills for academic success, the teaching of these skills should be the shared responsibility of teachers of all disciplines.

Minimum skills that students should acquire by the end of **Grade 8** include the following:

C/T8.1 The student will communicate through application software.
- Compose and edit a multipage document at the keyboard, using word processing skills and the writing process steps.
- Communicate with spreadsheets by entering data and setting up formulas, analyzing data, and creating graphs or charts to visually represent data.
- Communicate with databases by defining fields and entering data, sorting, and producing reports in various forms.
- Use advanced publishing software, graphics programs, and scanners to produce page layouts.
- Integrate databases, graphics, and spreadsheets into word-processed documents.

C/T8.2 The student will communicate through networks and telecommunication.
- Use local and worldwide network communication systems.
- Develop hypermedia "home page" documents that can be accessed by worldwide networks.

C/T8.3 The student will have a basic understanding of computer processing, storing, retrieval, and transmission technologies and a practical appreciation of the relevant advantages and disadvantages of various processing, storage, retrieval, and transmission technologies.

C/T8.4 The student will process, store, retrieve, and transmit electronic information.
- Use search strategies to retrieve electronic information.
- Use electronic encyclopedias, almanacs, indexes, and catalogs to retrieve and select relevant information.
- Use laser discs with a computer in an interactive mode.
- Use local and wide-area networks and modem-delivered services to access and retrieve information from electronic databases.
- Use databases to perform research.

Earth Science

The Earth Science standards connect the study of the Earth's composition, structure, processes, and history; its atmosphere, fresh water, and oceans; and its environment in space. The standards emphasize historical contributions in the development of scientific thought about the Earth and space. The standards stress the interpretation of maps, charts, tables, and profiles; the use of technology to collect, analyze, and report data; and science skills in systematic investigation. Problem solving and decision making are an integral part of the standards, especially as they relate to the costs and benefits of utilizing the Earth's resources. Major topics of study include plate tectonics, the rock cycle, Earth history, the oceans, the atmosphere, weather and climate, and the solar system and universe.

ES.1 The student will plan and conduct investigations in which
- volume, area, mass, elapsed time, direction, temperature, pressure, distance, density, and changes in elevation/depth are calculated utilizing the most appropriate tools;
- technologies, including computers, are used to collect, analyze, and report data and to demonstrate concepts and simulate experimental conditions;
- scales, diagrams, maps, charts, graphs, tables, and profiles are constructed and interpreted;
- variables are manipulated with repeated trials; and
- a scientific viewpoint is constructed and defended.

ES.2 The student will demonstrate scientific reasoning and logic by
- analyzing how science explains and predicts the interactions and dynamics of complex Earth systems;
- recognizing that evidence is required to evaluate hypotheses and explanations;
- comparing different scientific explanations for the same observations about the Earth;
- explaining that observation and logic are essential for reaching a conclusion;
- evaluating evidence for scientific theories related to plate tectonics, the structure of the Earth, and its ancient age and origin; and
- making informed judgments related to resource use and its effects on Earth systems.

ES.3 The student will investigate and understand how to read and interpret maps, globes, models, charts, and imagery. Key concepts include
- maps (bathymetric, geologic, topographic, and weather) and star charts;
- imagery (aerial photography and satellite images);
- direction and distance measurements on any map or globe; and
- location by latitude and longitude and topographic profiles.

ES.4 The student will investigate and understand the characteristics of the Earth including
- plate tectonics;
- water in all three states;
- position of the Earth in the solar system; and
- effects of density differences and energy transfer on the activities of the atmosphere, oceans, and Earth's interior.

ES.5 The student will investigate and understand how to identify major rock-forming and ore minerals based on physical and chemical properties. Key concepts include
- properties including hardness, color and streak, luster, cleavage, fracture, and unique properties; and
- uses of minerals.

ES.6 The student will investigate and understand how to identify common rock types based on mineral composition and textures and the rock cycle as it relates to the transformation of rock types. Key concepts include
- igneous (intrusive and extrusive);
- sedimentary (clastic and chemical); and
- metamorphic (foliated and unfoliated) rocks.

ES.7 The student will investigate and understand the differences between renewable and nonrenewable resources. Key concepts include
- fossil fuels, minerals, rocks, water, and vegetation;
- advantages and disadvantages of various energy sources;
- resources found in Virginia;
- use of resources and their effects on standards of living; and
- environmental costs and benefits.

ES.8 The student will investigate and understand geologic processes including plate tectonics. Key concepts include

- how geologic processes are evidenced in the physiographic provinces of Virginia including the Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau;
- processes (faulting, folding, volcanism, metamorphism, weathering, erosion, deposition, and sedimentation) and their resulting features; and
- tectonic processes (subduction, rifting and sea floor spreading, and continental collision).

ES.9 The student will investigate and understand how freshwater resources are influenced by geologic processes and the activities of humans. Key concepts include

- processes of soil development;
- development of karst topography;
- identification of groundwater zones including water table, zone of saturation, and zone of aeration;
- identification of other sources of fresh water including aquifers with reference to the hydrologic cycle; and
- dependence on freshwater resources and the affects of human usage on water quality.

ES.10 The student will investigate and understand that many aspects of the history and evolution of the Earth and life can be inferred by studying rocks and fossils. Key concepts include

- traces or remains of ancient, often extinct, life are preserved by various means in many sedimentary rocks;
- superposition, cross-cutting relationships, and radioactive decay are methods of dating bodies of rock;
- absolute and relative dating have different applications but can be used together to determine the age of rocks and structures; and
- rocks and fossils from many different geologic periods and epochs are found in Virginia.

ES.11 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

- physical and chemical changes (tides, waves, currents, sea level and ice cap variations, upwelling, and salinity concentrations);
- importance of environmental, geologic, and economic implications;
- systems interactions (energy transfer, weather, and climate);
- features of the sea floor (continental margins, trenches, mid-ocean ridges, and abyssal plains) reflect tectonic processes; and
- public policy issues concerning the oceans.

ES.12 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

- scientific evidence for atmospheric changes over geologic time;
- current theories related to the effects of early life on the chemical makeup of the atmosphere;
- comparison of the Earth's atmosphere to that of other planets;
- atmospheric regulation mechanisms; and
- potential atmospheric compositional changes due to human, biologic, and geologic activity.

ES.13 The student will investigate and understand that energy transfer between the sun, Earth, and the Earth's atmosphere drives weather and climate on Earth. Key concepts include

- observation and collection of weather data;
- prediction of weather patterns; and
- weather phenomena and the factors that affect climate.

ES.14 The student will investigate and understand the planets and other members of the solar system; the history and contributions of the space program; and concepts related to the origin and evolution of the solar system, galaxy, and universe. Key concepts include

- characteristics of the sun, planets, their moons, comets, meteors, and asteroids; and
- cosmology and the origin of stars and stellar systems (the Big Bang, the solar nebular theory, stellar evolution, star systems, nebulae, constellations, and galaxies).

Biology

The standards for Biology are designed to provide students with a detailed understanding of living systems. Emphasis continues to be placed on the skills necessary to examine alternative scientific explanations, actively conduct controlled experiments, analyze and communicate information, and acquire and use scientific literature. The history of biological thought and the evidence that supports it are explored and provide the foundation for investigating biochemical life processes, cellular organization, mechanisms of inheritance, dynamic relationships among organisms, and the change in organisms through time. The importance of scientific research that validates or challenges ideas is emphasized at this level.

BIO.1 The student will plan and conduct investigations in which
- observations of living things are recorded in the lab and in the field;
- hypotheses are formulated based on observations;
- variables are defined and investigations are designed to test hypotheses;
- graphing and arithmetic calculations are used as tools in data analysis;
- conclusions are formed based on recorded quantitative and qualitative data;
- impacts of sources of error inherent in experimental design are identified and discussed;
- validity of data is determined;
- alternative explanations and models are recognized and analyzed;
- appropriate technology is used for gathering and analyzing data and communicating results; and
- research is used based on popular and scientific literature.

BIO.2 The student will investigate and understand the history of biological concepts. Key concepts include
- evidence supporting the cell theory;
- scientific explanations of the development of organisms through time;
- causative agents of disease;
- the evolution of the DNA model; and
- the collaborative efforts of scientists, past and present.

BIO.3 The student will investigate and understand biochemical principles essential for life. Key concepts include
- water chemistry and its impact on life processes;
- the structure and function of macromolecules;
- the nature of enzymes; and
- the significance of and relationship between photosynthesis and respiration.

BIO.4 The student will investigate and understand relationships between cell structure and function. Key concepts include
- characterizing prokaryotic organisms;
- exploring the diversity and variation of eukaryotes;
- building analogies between the activities of a single cell and a whole organism; and
- modeling the cell membrane, cell communication, and cell recognition.

BIO.5 The student will investigate and understand life functions of monerans, protists, fungi, plants, and animals, including humans. Key concepts include
- how their structures are alike and different;
- comparison of their metabolic activities;
- analyses of their responses to the environment;
- maintenance of homeostasis;
- human health issues, human anatomy, body systems, and life functions;
- how viruses compare with organisms; and
- observation of local organisms when applicable.

BIO.6 The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include
- cell division;
- sex cell formation;
- cell specialization;
- prediction of inheritance of traits based on the laws of heredity;
- effects of genetic recombination and mutation;
- events involved in the construction of proteins; and
- exploration of the impact of DNA technologies.

BIO.7 The student will investigate and understand bases for modern classification systems. Key concepts include
- structural similarities in organisms;
- fossil record interpretation;

- comparison of developmental stages in different organisms;
- examination of protein similarities and differences among organisms;
- comparison of DNA sequences in organisms;
- systems of classification that are adaptable to new scientific discoveries; and
- examination of local flora and fauna where applicable.

BIO.8 The student will investigate and understand how populations change through time. Key concepts include

- examining evidence found in fossil records;
- investigating how variation of traits, reproductive strategies, and environmental pressures impact on the survival of populations;
- recognizing how adaptations lead to natural selection; and
- exploring how new species emerge.

BIO.9 The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include

- interactions within and among populations including carrying capacities, limiting factors, and growth curves;
- nutrient cycling with energy flow through ecosystems;
- succession patterns in ecosystems;
- the effects of natural events and human influences on ecosystems; and
- analysis of local ecosystems.

Chemistry

The Chemistry standards are designed to provide students with a detailed understanding of the interaction of matter and energy. This interaction is investigated through the use of laboratory techniques, manipulation of chemical quantities, and problem-solving applications. Scientific methodology will be employed in experimental and analytical investigations, and concepts will be illustrated with practical applications.

Technology including graphing calculators and computers will be employed where feasible. Students will understand and use safety precautions with chemicals and equipment. The standards emphasize qualitative and quantitative study of substances and the changes that occur in them. In meeting the chemistry standards, students will be encouraged to share their ideas, use the language of chemistry, discuss problem-solving techniques, and communicate effectively.

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

- designated laboratory techniques;
- safe use of chemicals and equipment;
- proper response to emergency situations;
- multiple variables are manipulated with repeated trials;
- accurate recording, organizing, and analysis of data through repeated trials;
- mathematical and procedural error analysis; and
- mathematical manipulations (SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, dimensional analysis, use of scientific calculator).

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

- mass/atomic number;
- isotopes/half-lives/nuclear particles;
- particle/mass charge;
- families/groups;
- series/periods;
- trends/patterns: atomic/nuclear radii, electronegativity, shielding effect;

- electron configurations/oxidation numbers;
- chemical/physical properties; and
- historical/quantum models.

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

- nomenclature;
- balancing chemical equations;
- writing chemical formulas—molecular, structural, empirical, and Lewis diagrams;
- bonding types—ionic, covalent;
- reaction types—synthesis, decomposition, single and double replacement, oxidation-reduction, neutralization, nuclear, exothermic and endothermic, spontaneous/non-spontaneous, dissociation ionization;
- physical and chemical equilibrium; and
- reaction rates and kinetics: activation energy, catalysis, degree of randomness.

CH.4 The student will investigate and understand that quantities in a chemical reaction are based on molar relationships. Key concepts include

- avogadro's principle, molar volume;
- stoichiometric relationships;
- partial pressure;
- gas laws;
- solution concentrations;
- chemical equilibrium; and
- acid/base theory: strong/weak electrolytes, dissociation/ionization (pH, pOH), and titration.

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

- pressure, temperature, and volume;
- vapor pressure;
- partial pressures;
- phase changes;
- molar heats of fusion and vaporization;
- specific heat capacity;
- solutions; and
- colligative properties.

CH.6 The student will investigate and understand how basic chemical principles relate to other areas of chemistry. Key concepts include

- organic and biochemistry;
- nuclear chemistry; and
- environmental chemistry.

Physics

The Physics standards emphasize a more complex understanding of experimentation, the analysis of data, and the use of reasoning and logic to evaluate evidence. The use of mathematics, including algebra, inferential statistics, and trigonometry, is important, but conceptual understanding of physical systems remains a primary concern. Students build on basic physical science principles by exploring in depth the nature and characteristics of energy and its dynamic interaction with matter. Key areas covered by the standards include force and motion, kinetic molecular theory, energy transformations, wave phenomena and the electromagnetic spectrum, light, electricity, fields, and non-Newtonian physics. The standards stress the practical application of physics in other areas of science and technology and how physics affects our world.

PH.1 The student will investigate and understand how to plan and conduct investigations in which

- the components of a system are defined;
- instruments are selected and used to extend observations and measurements of mass, volume, temperature, heat exchange, energy transformations, motion, fields, and electric charge;
- information is recorded and presented in an organized format;
- metric units are used in all measurements and calculations;
- the limitations of the experimental apparatus and design are recognized;
- the limitations of measured quantities through the appropriate use of significant figures or error ranges are recognized; and
- data gathered from non-SI instruments are incorporated through appropriate conversions.

PH.2 The student will investigate and understand how to analyze and interpret data. Key concepts include
- a description of a physical problem is translated into a mathematical statement in order to find a solution;
- relationships between physical quantities are determined using the shape of a curve passing through experimentally obtained data;
- the slope of a linear relationship is calculated and includes appropriate units;
- interpolated, extrapolated, and analyzed trends are used to make predictions;
- inferential statistical tests are applied in evaluating experimental data; and
- analysis of systems employs vector quantities utilizing trigonometric and graphical methods.

PH.3 The student will investigate and understand how to demonstrate scientific reasoning and logic. Key concepts include
- analysis of primary sources to develop and refine research hypotheses;
- analysis of how science explains and predicts relationships; and
- evaluation of evidence for scientific theories and how new discoveries may either modify existing theories or result in establishing a new paradigm.

PH.4 The student will investigate and understand how applications of physics affect the world. Key concepts include
- principles with examples from the real world; and
- exploration of the roles and contributions of science and technology.

PH.5 The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include
- linear motion;
- uniform circular motion;
- curvilinear motion;
- Newton's laws of motion;
- gravitation;
- celestial mechanics; and
- work, power, and energy.

PH.6 The student will investigate and understand that quantities including mass, energy, momentum, and charge are conserved. Key concepts include
- kinetic and potential energy;
- elastic and inelastic collisions; and
- electric power and circuit design.

PH.7 The student will investigate and understand that the kinetic molecular theory can be applied to solve quantitative problems involving pressure, volume, and temperature.

PH.8 The student will investigate and understand that energy can be transferred and transformed to provide usable work. Key concepts include
- transformation of energy among forms, including mechanical, thermal, electrical, gravitational, chemical, and nuclear; and
- efficiency of systems.

PH.9 The student will investigate and understand how to use models of transverse and longitudinal waves to interpret wave phenomena. Key concepts include
- wave characteristics (period, wavelength, frequency, amplitude and phase);
- fundamental wave processes (reflection, refraction, diffraction, interference, standing waves, polarization, Doppler effect); and
- light and sound in terms of wave models.

PH.10 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
- the properties and behaviors of radio, microwaves, infra-red, visible light, ultra-violet, X-rays, and gamma rays; and
- current applications based on the wave properties of each band.

PH.11 The student will investigate and understand how light behaves in the fundamental processes of reflection, refraction, and image formation in describing optical systems. Key concepts include
- application of the laws of reflection and refraction;
- construction and interpretation of ray diagrams;
- development and use of mirror and lens equations; and
- predictions of type, size, and position of real and virtual images.

PH.12 The student will investigate and understand how to use the field concept to describe the effects of electric, magnetic, and gravitational forces. Key concepts include
- inverse square laws;
- Newton's law of universal gravitation;
- Coulomb's law; and

- operating principles of motors, generators, and cathode ray tubes.

PH.13 The student will investigate and understand how to diagram and construct basic electrical circuits and explain the function of various circuit components. Key concepts include

- Ohm's law; and
- series, parallel, and combined circuits.

PH.14 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 include

- wave/particle duality;
- wave properties of matter;
- matter/energy equivalence;
- quantum mechanics and uncertainty;
- relativity;
- nuclear physics;
- solid state physics;
- superconductivity; and
- radioactivity.