Physics

Introduction

The *Science Standards of Learning* for Virginia Public Schools identify academic content for essential components of the science curriculum at different grade levels. Standards are identified for kindergarten through grade five, for middle school, and for a core set of high school courses — Earth Science, Biology, Chemistry, and Physics. Throughout a student's science schooling from kindergarten through grade six, content strands, or topics are included. The Standards of Learning in each strand progress in complexity as they are studied at various grade levels in grades K-6, and are represented indirectly throughout the high school courses. These strands are

- Scientific Investigation, Reasoning, and Logic;
- Force, Motion, and Energy;
- Matter;
- Life Processes;
- Living Systems;
- Interrelationships in Earth/Space Systems;
- Earth Patterns, Cycles, and Change; and
- Earth Resources.

Five key components of the science standards that are critical to implementation and necessary for student success in achieving science literacy are 1) Goals; 2) K-12 Safety; 3) Instructional Technology; 4) Investigate and Understand; and 5) Application. It is imperative to science instruction that the local curriculum consider and address how these components are incorporated in the design of the kindergarten through high school science program.

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 achieve the following objectives:

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 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; and
- 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; and
   - patience and persistence.
8. Develop an understanding of the interrelationship of science with technology, engineering and mathematics.
9. Explore science-related careers and interests.

K-12 Safety

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

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

Teachers must be knowledgeable of the properties, use, and proper disposal of all chemicals that may be judged as hazardous prior to their use in an instructional activity. Such information is referenced through Materials Safety Data Sheets (MSDS). 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 coming in contact with natural hazards, such as poison ivy, ticks, mushrooms, insects, spiders, and snakes;
- engaging in field activities in, near, or over bodies of water;
- handling glass tubing and other glassware, sharp objects, and labware;
- handling natural gas burners, Bunsen burners, and other sources of flame/heat;
- working in or with direct sunlight (sunburn and eye damage);

- using extreme temperatures and cryogenic materials;
- handling hazardous chemicals including toxins, carcinogens, and flammable and explosive materials;
- producing acid/base neutralization reactions/dilutions;
- producing toxic gases;
- generating/working with high pressures;
- working with biological cultures including their appropriate disposal and recombinant DNA;
- handling power equipment/motors;
- working with high voltage/exposed wiring; and
- working with 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 referenced:

- OSHA (Occupational Safety and Health Administration);
- ISEF (International Science and Engineering Fair) rules; and
- public health departments' and school divisions' protocols.

Instructional Technology

The use of current and emerging technologies is essential to the K-12 science instructional program. Specifically, technology must accomplish the following:

- 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), presentation of one's ideas (presentation software), and resource management (project management software).
- Be readily available and regularly used as an integral and ongoing part of 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, video-microscopes, graphing calculators, probeware, geospatial technologies, online communication, software and appropriate hardware, as well as other emerging technologies.
- Be reflected in the "instructional strategies" generally developed at the 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 teaching these skills is a shared responsibility of teachers of all disciplines and grade levels.

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; and
- 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, using the information to explain new phenomena, 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 facts, principles, and other information to produce a new idea, plan, procedure, or product; and
- make judgments about information in terms of its 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 school division will develop and refine to meet the intent of the *Science Standards of Learning*.

Application

Science provides the key to understanding the natural world. The application of science to relevant topics provides a context for students to build their knowledge and make connections across content and subject areas. This includes applications of science among technology, engineering, and mathematics, as well as within other science disciplines. Various strategies can be used to facilitate these applications and to promote a better understanding of the interrelated nature of these four areas.

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 and trigonometry, is important, but conceptual understanding of physical systems remains a primary concern. Students build on basic physical science principles by exploring in-depth the nature and characteristics of energy and its dynamic interaction with matter. Key areas covered by the standards include force and motion, energy transformations, wave phenomena and the electromagnetic spectrum, electricity, fields, and non-Newtonian physics. The standards stress the practical application of physics in other areas of science, technology, engineering, and mathematics. The effects of physics on our world are investigated through the study of critical, contemporary global topics.

The Physics standards continue to focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence. The nature of science includes the concept that science can provide explanations about nature and can predict potential consequences of actions, but cannot be used to answer all questions.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.