Science Standards of Learning

for Virginia Public Schools

Board of Education
Commonwealth of Virginia

October 2018

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Board of Education
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Notice to Reader

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Preface

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

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

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

Introduction

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

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

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

Goals

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

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

Investigate and Understand

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

- Asking questions and defining problems
- Planning and carrying out investigations
- Interpreting, analyzing, and evaluating data
- Constructing and critiquing conclusions and explanations
- Developing and using models
- Obtaining, evaluating, and communicating information

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

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

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

Nature of Science

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

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

Science and Engineering Practices

Science utilizes observation and experimentation along with existing scientific knowledge, mathematics, and engineering technologies to answer questions about the natural world. Engineering employs existing scientific knowledge, mathematics, and technology to create, design, and develop new devices, objects or technology to meet the needs of society.

By utilizing both scientific and engineering practices in the science classroom, students develop a deeper understanding and competences with techniques at the heart of each discipline.

K-12 Safety

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

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

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

The following sources offer further guidance on science safety:

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

Instructional Technology

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

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

Profile of a Virginia Graduate

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

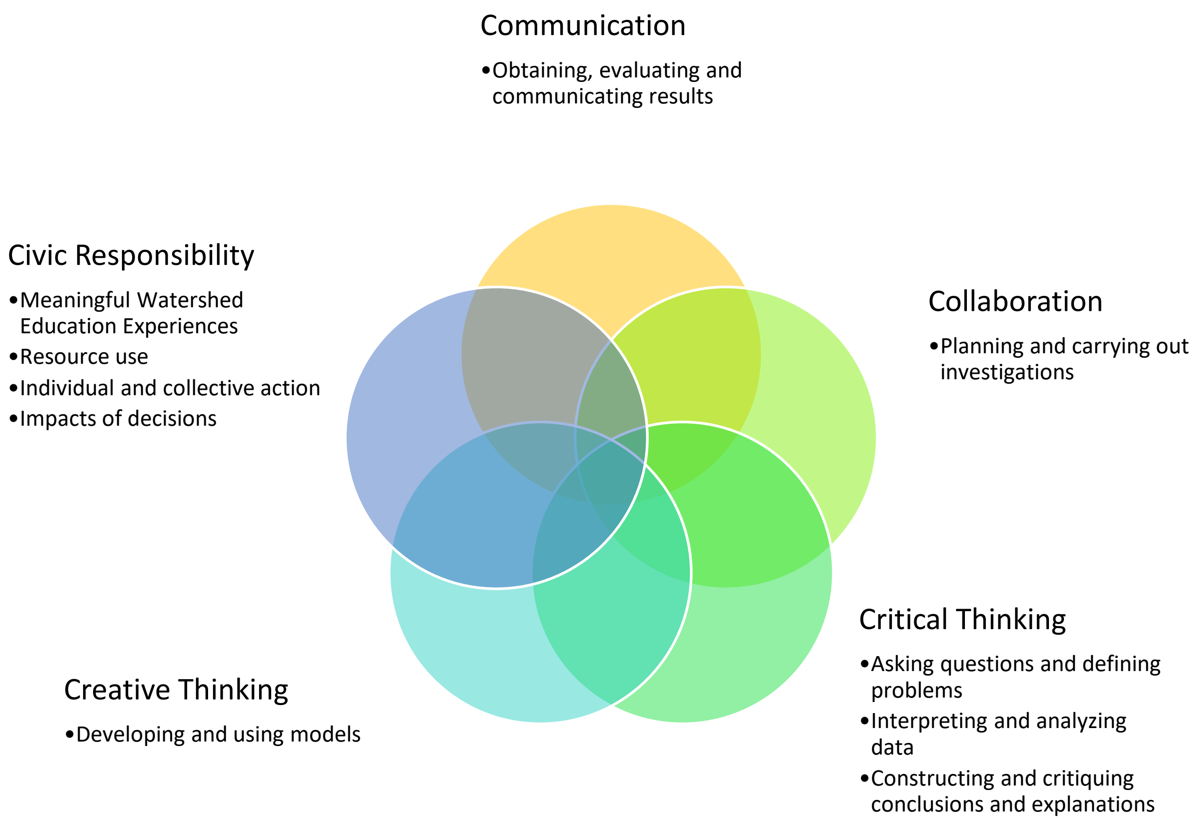

Figure 1: Visual representation of the science skills and processes aligned to the Profile of a Virginia Graduate

Chemistry

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

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

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

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

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

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

d) constructing and critiquing conclusions and explanations
- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena or design solutions
- compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence
- construct arguments or counterarguments based on data and evidence
- differentiate between scientific hypothesis, theory, and law

e) developing and using models
- evaluate the merits and limitations of models
- develop, revise, and/or use models based on evidence to illustrate or predict relationships
- use models and simulations to visualize and explain the movement of particles, to represent chemical reactions, to formulate mathematical equations, and to interpret data sets

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

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

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

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

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

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

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

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

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

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