SCIENCE

Virginia

GRADE	SCORES		TOTAL SCORE
A-	Content and Rigor	6/7	9/10
	Clarity and Specificity	3/3	

REPORT CARD

Content & Rigor	**5.8**
Scientific Inquiry & Methodology	2
Physical Science	7
Physics	5
Chemistry	7
Earth & Space Science	7
Life Science	7
Clarity & Specificity	**3.0**

Average numerical evaluations

Overview

The Old Dominion's science standards are among the few that we would cheerfully recommend as models for other states (and for drafters of "common" standards for this field). They are thorough and rigorous, particularly in the areas of mathematical applications and evolution, and they clearly provide a solid foundation for a rigorous K-12 science curriculum.

Organization of the Standards

Virginia's K-6 standards are divided first into seven strands (scientific investigation, reasoning, and logic; force, motion, and energy; matter; life processes; interrelationships in earth/space systems; earth patterns, cycles, and change; and earth resources), which are common across all grades. For each strand, the state presents grade-specific standards. Finally, a list of "key concepts" that students must learn further clarifies the standards. For instance, under the "life processes" strand in fourth grade, students "will investigate and understand basic plant anatomy and life processes," with key concepts that include photosynthesis and the structures of typical plants.

The standards for grades 7-12 are presented similarly, except that they are organized by course rather than by grade: for life science, physical science, earth science, biology, chemistry, and physics. A "test blueprint" provided along with the standards indicates that students are to be assessed in life science and physical science by eighth grade. Thus, in this review, we refer to all other course standards as high school standards.

In addition, Virginia provides a separate curriculum framework that further clarifies "the minimum content that all teachers should teach and all students should learn."

Content and Rigor

The content material in the Virginia standards is well written and well organized by a group of authors whose knowledge of science is clearly substantial. The rigorous material is almost always grade-level appropriate, and it is a pleasure to see mathematical expressions used where needed. The word "calculate" appears regularly in the documents, a sure sign that the standards are on the right track.

Document(s) Reviewed

► *Virginia Science Standards of Learning: Standards and Curriculum Framework.* January 2010. Accessed from: http://www.doe.virginia.gov/testing/sol/standards_docs/science/review.shtml

Scientific Inquiry and Methodology

Virginia's inquiry and process material, contained under the strand of "scientific investigation, reasoning, and logic," is perhaps the standards' lowest point. This material is presented with no explicit connection to Virginia's content standards or with any examples of how they may work into classroom activities. Further, Old Dominion's inquiry standards, while appropriate, are excessively brief and are often repetitious or vague. This leaves a disjunction between the aspirations of the writers and what will be taught in classrooms. What's more, for grades five through twelve, the writers state:

> **The nature of science includes the concepts that scientific explanations…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…but cannot be used to answer all questions. (grades 5-12)**

Yet, the history of science and the philosophical issue of the limits of inquiry are never mentioned in the grade-specific expectations.

Physical Science

The physical sciences are presented very well, especially in Kindergarten through sixth grade. The treatment of simple machines in third grade is elegant. Simple ideas of electricity and magnetism are introduced in fourth grade, with even a bit of electromagnetic interaction. Waves, sound, and light are nicely introduced in fifth grade; the instructor is even provided with a clear picture of a longitudinal wave. In sixth grade, physical science emphasizes energy and the atomic structure of matter, leading into some significant elements of chemistry. Energy is treated properly, if not rigorously enough. Laudably, the standards distinguish between kinetic and potential energy in a way that avoids confusion with the distinction between such types of potential energy as chemical, electrical, or mechanical.

High School Physics

The high school physics standards cover all of the essential content, and much of it quite well. For example, mechanics (notably kinematics) is handled well—as are waves, in all their manifestations (general wave theory, sound, and light).

There are a few drawbacks, however. While the coverage is comprehensive, the standards rush over some key concepts: Dynamics and kinematics are scrambled together, and the discussions of energy and Newton's laws are disappointingly brief.

Basic electricity is covered, but as is too often the case in high school physics standards, Ampère's and Faraday's laws are slighted; they are mentioned only qualitatively and in passing. Here is a lost opportunity to convey a real understanding of electromagnetic radiation.

All of modern physics (most of physics since 1900 or so) is covered in a single, rather ambitious standard. While this format could well frame recent additions to physics thought, instead it simply abridges the list of student expectations, boiling them down to this:

> **Explain that the motion of objects traveling near or approaching the speed of light does not follow Newtonian mechanics but must be treated within the theory of relativity.**
>
> **Describe the relationship between the Big Bang theory timeline and particle physics.**
>
> **Describe the structure of the atomic nucleus, including quarks. (high school physics)**

The first of these statements is negative and gives no hint of why one must do this or what supplements or supplants Newton's laws. The second is so broad as to cover a library of physics research. The third is a subject for a fat textbook. If all the salient areas of physics were as well covered as mechanics (especially kinematics) and waves, Virginia's standards would move from good to excellent.

High School Chemistry

Virginia's chemistry standards are both clear and rigorous. They deftly maneuver through difficult concepts—especially through the curriculum framework. Some examples:

> **Electronegativity is the measure of the attraction of an atom for electrons in a bond. Electronegativity increases from left to right within a period and decreases from top to bottom within a group.**
>
> **Name binary covalent/molecular compounds.**
>
> **Name binary ionic compounds (using the Roman numeral system where appropriate). (high school chemistry)**

A long and rigorous standard both requires students to calculate stoichiometric values and explains the relationship between various units:

> **Perform stoichiometric calculations involving the following relationships: mole-mole; mass-mass; mole-mass; mass-volume; mole-volume; volume-volume; mole-particle; mass-particle; and volume-particle. (high school chemistry)**

A bit of nit-picking, though: This standard could have been made even stronger if the writers had added "volume of a gas at STP or at specified conditions" whenever the volume of a gas is involved in a question.

Further examples illustrate the breadth of Virginia's chemistry standards:

> **Perform titrations in a laboratory setting using indicators.**
>
> **Calculate energy changes, using molar heat of fusion and molar heat of vaporization…and specific heat capacity.**
>
> **Perform calculations involving the molarity of a solution, including dilutions. (high school chemistry)**

Collectively, these standards will provide students with excellent preparation for college-level chemistry.

Earth and Space Science

The content coverage in earth and space science is also good, if not quite on par with chemistry. Plate tectonics and weather systems are particularly well covered.

The content provided in the curriculum framework adds significant value as well. For example, the fifth-grade standard, "Describe the structure of Earth in terms of its major layers—crust, mantle, and outer core and inner core—and how Earth's interior affects the surface," is explained further with the following:

> **Scientific evidence indicates that Earth is composed of four concentric layers—crust, mantle, outer core, and inner core—each with its own distinct characteristics. The outer two layers are composed primarily of rocky material. The innermost layers are composed mostly of iron and nickel. Pressure and temperature increase with depth beneath the surface. (grade 5)**

There is also solid development of the standards from grade to grade. A follow-up to the fifth-grade example above states: "Earth consists of a solid, mostly iron inner core; a liquid, mostly iron outer core; a crystalline but largely plastic mantle; and a rocky, brittle crust" (high school earth science).

Virginia's standards do fall slightly short in a few places. The mechanics and details of exciting phenomena like earthquakes, volcanoes, and tsunamis are slighted, for example. These phenomena are often in the news, and they can pose hazards for which students even in low-risk areas ought to be prepared (as the fall 2011 seismic events in Virginia underscore). No matter the locale, practical knowledge has its relevance.

Further, some important content normally seen in earlier grades is postponed to high school, although younger students would enjoy subjects such as mineral identification.

Life Science

While most of the Virginia standards are strong, the life sciences are the best of the bunch. For example, there is an entire second-grade unit on the white-tailed deer. A similarly well-developed fourth-grade standard includes an excellent explanation of the fact that plant seeds contain embryos.

Fifth-grade students learn about cells and their organelles—matters usually postponed to junior-high grades. The materials for seventh and eighth grades include good coverage of physiology, full coverage of genetics and heredity, including DNA and chromosomes, and excellent treatment of evolution. Many high school biology courses barely match what is done here, yet the presentation is all fully within the grasp of a middle-school student.

The high school materials could likely be used for an Advanced Placement course but are certainly appropriate for the regular course offering, given the excellent background established in middle school. Biochemistry concepts are sophisticated and well explained; genetics and molecular biology are outstanding. The unit on physiological systems is exceptional, and the treatment of ecology and evolution is well above average.

Indeed, Virginia's handling of evolution deserves special mention. The state incorporates evolution into the standards at an early grade:

> **Fossils provide information about living systems that were on Earth years ago. (grade 2)**

The standards go further to present interesting (and relevant) contextual background on fossils:

> **Virginia's state fossil, Chesapecten jeffersonius, is a large extinct species of scallop that dates to approximately 4.5 million years ago. It was the first fossil ever described in North America and is named after Thomas Jefferson, one of our founding fathers, and an amateur paleontologist. (grade 2)**

Seventh and eighth grades also offer an extensive coverage of evolution equivalent to or surpassing most states' high school offerings, and as noted above, the high school treatment is likewise outstanding.

With so many strengths, especially in chemistry and life sciences, Virginia receives a solid score of six out of seven for

content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

Navigating the Virginia standards—as well as its supplemental curriculum framework—is a pleasure. Material is cleanly presented and easily found. The *Framework's* "essential understandings," which provide background material for teachers, are beautifully written and would be useful to any teacher, especially the novice. For example, heat and temperature are often conflated in standards; Virginia's "essential understanding" on the topic ensures clarity of content:

> **Heat and temperature are not the same thing. Heat is the transfer of thermal energy between substances of different temperature. As thermal energy is added, the temperature of a substance increases.**
>
> **Temperature is a measure of the average kinetic energy of the molecules of a substance. Increased temperature means greater average kinetic energy of the molecules in the substance being measured.…The temperature of absolute zero (–273ºC/0 K) is the theoretical point at which molecular motion stops. (grades 7-8 physical science)**

(As everything else is covered extremely well, we can forgive the neglect of the zero-point motion that is characteristic of all matter at 0 K, and of the fact that the temperature of a substance does not increase during phase change.)

Unfortunately, essential equations, including Newton's law of universal gravitation and Coulomb's law, are attached to less specific and less satisfactory statements such as "describe the attractive or repulsive forces between objects relative to their forces and distance between them (Coulomb's Law)" and "describe the attraction of particles (Newton's Law of Universal Gravitation)." The Old Dominion would be wise to reincorporate them into the standards.

Virginia's successful effort does not involve magic or gimmickry. Every state could (and should) emulate these standards—if not literally, then at least as a model of serious thinking about science curricula. The score of three out of three for clarity and specificity is well earned. (See Appendix A: Methods, Criteria, and Grading Metric.)