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To: Paula Klonowski, Science Coordinator  
Virginia Department of Education  
sciencesol@doe.virginia.gov

From: W. W. "Ted" Bennett, Chairman of the Board  
Patrick J. Dexter, President  
Virginia Mathematics and Science Coalition

Subject: Revisions to Proposed Revised Science Standards  
of Learning

The Virginia Mathematics and Science Coalition commends the proposed revisions that have retained the best of what was good in the Science Standards of Learning and added key components which make the Standards stronger and clearer. The Coalition recommends the following changes to make the standards even stronger and clearer.

### 1. Nature of Science

- Commend the emphasis on "understanding ...the nature of science, which now appears in the "point-one" standard of every grade and course and we look forward to it being clearly articulated in the curriculum framework.
- Recommend generally that the nature of science be explicitly addressed for every grade level and course.

The nature of science is mentioned in the Proposed Revised Science Standards of Learning. However, the nature of science needs to be explicitly addressed since many teachers do not know or have not considered what the nature of science is. Extensive research indicates that students do not learn the nature of science implicitly by practicing process skills or doing investigations. Rather, research indicates that the nature of science should be a stated goal and be explicitly addressed in the lesson.<sup>1</sup>

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<sup>1</sup> Abd-El-Khalick, F., Bell, R.L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, 82, 417-436.

One helpful description of the nature of science breaks the concept into a world view, the basis of scientific inquiry, and the notion of scientific enterprise.<sup>2</sup>

#### Scientific World View

- The World Is Understandable
- Scientific Ideas Are Subject To Change
- Scientific Knowledge Is Durable
- Science Cannot Provide Complete Answers to All Questions

#### Scientific Inquiry

- Science Demands Evidence
- Science Is a Blend of Logic and Imagination
- Science Explains and Predicts
- Scientists Try to Identify and Avoid Bias
- Science Is Not Authoritarian

#### Scientific Enterprise

- Science Is a Complex Social Activity
- Science Is Organized Into Content Disciplines and Is Conducted in Various Institutions
- There Are Generally Accepted Ethical Principles in the Conduct of Science
- Scientists Participate in Public Affairs Both as Specialists and as Citizens

Other commentators have offered additional thoughts on the nature of science that may be useful.<sup>3</sup>

- Scientific knowledge is empirically based.
- Scientific knowledge may be revised with new evidence or new perspectives on existing evidence.
- Scientific knowledge is the product of observation and inference.
- Scientific knowledge is the product of creative thinking.
- Scientific knowledge is subjective in that it is theory-laden.
- Scientific knowledge may be influenced by social and cultural contexts.
- Scientific knowledge is not absolute.
- There is not a single scientific method, but rather, scientists use a variety of methods to develop scientific knowledge.
- Scientific laws and theories are different kinds of knowledge—theories do not change into laws.

➤ Specific standards to address the nature of science more explicit include the following:.

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<sup>2</sup> American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

<sup>3</sup> Lederman, N. G., Abd-El-Khalick, F., Bell, R.L., & Schwartz, R. S. (2002). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39, 497-521.

- **Physical Science**
  - Recommend adding to PS.1
    - n) Scientific knowledge is based on empirical evidence.
    - o) There is no single scientific method. There are many ways to generate scientific knowledge, one of which is the experimental method.
- **Earth Science**
  - Recommend adding to ES.2
    - d) evidence is evaluated for scientific theories and laws.
- **Biology**
  - Recommend adding to BIO.1
    - k) differentiation is made between a scientific hypothesis, ~~and~~ theory; and law
- **Physics**
  - Recommend adding to PH.3
    - c) evaluation of evidence for scientific theories and laws;

## 1. Current Applications

- Commend adding the use of “current applications” or real-world examples from grade 6 through chemistry in each of the "point-one" Standards to engage the students and to reinforce the content of the courses.
- Recommend that a similar introduction of "current applications” or examples from the real world also be included in the "point-one" level of the Standards for grades K through 5 and for physics. This will extend “current applications” of science to grades K-5, middle school courses, and high school courses.

## 2. Science, Technology, Engineering, and Mathematics

- Commend the new STEM introductory section entitled "Application" on page 7 for the clarification of the distinct role of Science compared to Technology, Engineering, and Mathematics and for the importance of understanding the interrelationships among these disciplines.
- Recommend that this “Application” section and the related Goal #8 on page 4 – which reads "Develop an understanding of the interrelationship of science with technology, engineering and mathematics" – be developed further with greater detail in the appropriate places in the Standards, as there is currently no mechanism in the Curriculum Framework to provide detail for components that appear in overall Introduction but not in the Standards of any grade or course.

- Recommend including the following clarification of science, technology, engineering, and mathematics in the “Application” section on page 7.

Science is a collaborative effort to expand understanding of the natural world. Science is the study and explanation of phenomena via systematic observation; measurement; experimentation and investigation; data collection, interpretation, analysis, and evaluation; development of conclusions; and formulation of theory. Scientists ask questions and solve problems. It includes:

- the skills and processes of inquiry,
- the body of knowledge derived from verifiable experimentation and systematic investigation and scrutiny in the face of new evidence, and
- the habits of mind underpinning rational inquiry (e.g., respect for data, demand for verification, questioning, intellectual honesty).

Scientists use technologies created by engineers to conduct their research. In turn, engineers use knowledge developed by scientists to inform the design of the technologies they create.

Technology in its broadest sense refers to tools. Tools can include a purposefully-chipped basalt pebble, a pencil, a microscope, a telescope, or a space suit. Technology also refers to computer, computer applications, and electronic communication devices. Technology enables science to advance and technology education preK-12 utilizes science and mathematics concepts in the design process.

Engineering creates products and processes that meet the needs of society. Engineers explore solutions through the “Design and Build” process. Engineering is applied science and its subject matter is derived from scientific knowledge. Applications of engineering occur throughout the traditional scientific fields.

Mathematics is the study of measurement, properties, and the relationships of quantities using numbers and symbols. Applied mathematics enables scientists to describe, model and simulate phenomena and to solve concrete problems.

### **3. Safety**

- Commend that classroom and field trip safety is mentioned in the introduction section.
- Recommend that safety be addressed for students for every grade level and course for personal and environmental health.

Safety is an important issue for the health of every student in the classroom and for living. In addition to being important for every student, it is important for the health of the environment. As experiments are conducted inside and outside the classroom, the health of self, others, and the environment are necessary considerations. The following additions to safety for living are based on the science in the SOL for each grade level or course.

➤ **Specific, grade-by-grade and subject area recommendations to reinforce safety are as follows:**

- **Kindergarten**  
Recommend adding to the "point-one" standard - science materials are used safely
- **Grade 1**  
Recommend adding to the "point-one" standard - science materials are used safely
- **Grade 2**  
Recommend adding to the "point-one" standard - plant and animal materials are handled safely and humanly
- **Grade 3**  
Recommend adding to the "point-one" standard - major conservation, health, and safety issues associated with life needs of animals in ecosystems
- **Grade 4**  
Recommend adding to the "point-one" standard - major conservation, health, and safety issues associated with electricity, plants and animals in their environment, and weather conditions.
- **Grade 5**  
Recommend adding to the "point-one" standard - major conservation, health, and safety issues associated with sound and light, organisms, and the impact of the constantly changing Earth's surface on humans
- **Grade 6**  
Commend 6.7 f) major conservation, health, and safety issues associated with watersheds
- **Life Science**  
Recommend adding to the "point-one" standard - major conservation, health, and safety issues are associated with living organisms
- **Physical Science**  
Commend PS.1 a) chemicals and equipment are used safely;
- **Earth Science**  
Recommend adding to the "point-one" standard - safe reactions in natural disasters are made explicit

- **Biology**  
Commend BIO.1 h) chemicals and equipment are used in a safe manner  
Recommend adding to the "point-one" standard -  
major conservation, health, and safety issues are associated with personal and environmental health
- **Chemistry**  
Commend CH.1 b) safe use of chemicals and equipment  
Recommend adding to CH.1 b) -  
... are applied to personal and environmental health
- **Physics**  
Recommend adding to the "point-one" standard -  
physics safety issues are applied to everyday living

#### 4. Unifying Concepts and Processes

- Recommend incorporating “unifying concepts and processes” as described in *National Science Education Standards* (p. 115, NRC, 1996).

As noted in the *National Science Education Standards (NSES)*, there is a necessity for students to develop an understanding of concepts and processes that span the multiple science and technology disciplines that students are exposed to at each grade level (K-12).

These concepts and processes are quoted below:

- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, change, and measurement
- Evolution and equilibrium
- Form and function (p. 115)

Through developing an understanding of these unifying concepts and processes, students gain a more holistic understanding of the multiple disciplines of science and technology. As noted in *NSES*, the unifying principles “provide students with productive and insightful ways of thinking about and integrating a range of basic ideas that explain the natural and designed world” (p. 115).

The five unifying concepts and principles listed above were carefully selected for inclusion in *NSES* based on the following parameters as quoted below:

- The concepts and processes provide connections between and among traditional scientific disciplines.
- The concepts and processes are fundamental and comprehensive.
- The concepts and processes are understandable and usable by people who will implement science programs.
- The concepts and processes can be expressed and experienced in a developmentally appropriate manner during K-12 science education. (p. 115)

Addition of the unifying concepts and processes to the listed goals in the front matter of Virginia’s science standards provides the following benefits and opportunities:

- Provides an opportunity for Virginia’s students to develop a fuller and richer understanding of science through purposeful connections between the various science disciplines (example: life science and physical science).
- Provides a rationale for integration across science units within a given grade level, as well as collaboration between grade levels and science disciplines, to support students’ holistic understanding of science.
- Provides a framework for implementation of proposed #8 (Develop an understanding of the interrelationship of science with technology, engineering and mathematics) and proposed #9 (Explore science-related careers and interests).

➤ Recommend adding on page 4 the following text to the listed goals:

10. Develop a holistic understanding of unifying concepts and processes that span the multiple science and technology disciplines that students are exposed to at each grade level in grades K through 12. These unifying concepts and processes are:

- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, change, and measurement
- Evolution and equilibrium
- Form and function

## 5. Chemistry

➤ Do not support the removal of “and oxidation numbers” from CH.2 (g) and “oxidation-reduction” from CH.3 (e).

A high school chemistry course which does not include these concepts does not prepare students for college chemistry or biology courses, or for the green job workforce and other technical trades, and does not provide the background needed to understand many green technologies.

## 6. Physics

- Recommend adding to PH.1 (g) the use of current applications to reinforce physics concepts to design solutions to needs
- Recommend that PH.4 be included in PH.1, as in other disciplines. If kept, then recommend revision: (b): exploration of the roles and contributions of science, engineering, and technology.
- Recommend examination of PH.12 objective set since many of these concepts are already included and these concepts could be added earlier. For example, (a) wave/particle duality is a component of PH.9 (particle nature of light). Matter/energy equivalence (c), nuclear energy (f),

and radioactivity (j) are part of PH.6 (mass/energy equivalence) and PH.7 transformation of energy among forms . . . nuclear.

The Virginia Mathematics and Science Coalition would be happy to provide volunteers to serve on various review committees related to the Virginia Standards of Learning and Curriculum Framework.

Thank you for your consideration of the Virginia Mathematics and Science Coalition's comments.