

Date: November 17, 2009

To: Virginia Board of Education

From: Julia H. Cothron, Ed.D.  
Executive Director  
MathScience Innovation Center

Subject: Revisions to Proposed Revised Science Standards of Learning &  
Curriculum Framework

The MathScience Innovation Center commends the Virginia Department of Education on revisions that place greater emphasis upon integration of math, science, engineering and technology, current applications, and the nature of science. The MathScience Innovation Center recommends that additional detail related to these revisions be included in the Standards and/or the Curriculum Framework.

**1. Goal 8: Develop an understanding of the interrelationships of science with technology, engineering and mathematics (p. 4) and Application (p. 7).**

The MathScience Innovation Center recommends that additional information be added on page 4 or 7.

Science is a collaborative effort to expand understanding of the natural world. Scientists research questions about the natural world through the process of inquiry, commonly known as “the scientific method.” Scientific advances provide engineers with the fundamental concepts to develop new technological products and processes.

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.

Engineering creates products and processes that meet the needs of society. Engineers explore practical questions and 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.

Technology (including engineering) has the mission of making effective tools for all human applications; it is applied math and science and its subject matter is derived from these disciplines. New technologies enable math and science to advance, e.g. microscopes, telescopes, satellites, computer hardware and software.

2. **Commend the addition of the phrase “current applications are used to reinforce science concepts” in Science 6, Life Science, Physical Science, Earth Science, Biology, Chemistry and Physics.**

The MathScience Innovation Center recommends the addition of the phrase “current applications are used to reinforce science concepts” in the K-5 level, especially grades 3-5. In addition, we recommend that the curriculum framework be strengthened to include scientific knowledge essential for understanding applications in engineering and nanoscience (addressed later in this document).

3. **Commend the attention given to alignment of the “Scientific, Investigation, Reasoning, and Logic” strand throughout K-12 and especially the increased emphasis on models and simulations.**

The Math Science Innovation Center recommends that the Standards and/or the Curriculum Framework be strengthened to include more detail on these changes. As part of recommendations for Engineering and Nanoscience, specific recommendations for additional emphasis will be provided.

4. **Commend the attention given to focusing the Standards on major concepts and including details in the curriculum framework.**

For this reason, the MathScience Innovation Center has focused many of its recommendations for Engineering and Nanoscience on the curriculum framework; these will be addressed in Items 6 and 7.

5. **Chemistry (CH.2 and CH.3).** 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 and does not provide the background needed to understand many green technologies.

6. **Engineering. Recommend the addition of language, such as the following, in the Standards and/or Curriculum Framework to facilitate the integration of engineering.**

Goals - 3 (page 3): Use technology to investigate phenomena and design solutions to meet needs.

Goals – 9 (page 4): Explore science and engineering related careers and interests.

Investigate (page 6). Designing, construction and interpreting models (commend); Understand (page 7) Arrange and combine important facts,

principles, and other information to produce a new idea, plan, procedure, or product (commend); Application (page 7) – commend.

Kindergarten, K.1 (Page 8). Recommend adding: (l) models are designed and built.

Kindergarten, Curriculum Framework, Overview (Page 3). Recommend modifying: Observations and ideas can be communicated through pictures, models, and discussion. Essential Knowledge and Skills (Page 3).  
Recommend adding: design and construct simple models.

Grade 1, 1.1 (Page 11). Recommend adding: (k) models are designed and built to solve a need.

Grade 1, Curriculum Framework, Overview (Page 3). Add: Engineers use models to design and build solutions to problems and needs.  
Essential Knowledge and Skills (Page 3). Recommend adding: Design and build a simple model to solve a problem.

Grade 2, 2.1 (Page 14). Recommend modifying (k): Simple physical models are designed and constructed to clarify explanations and show relationships.

Grade 2, Curriculum Framework, Overview (Page 3). Recommend modifying: By designing and constructing simple models, it is sometimes easier to understand how real things work and to solve problems.

Essential Knowledge and Skills (Page 3). Recommend adding: Design and build a simple model to solve a problem.

Grade 3, 3.1 (Page 17). Recommend adding: (l): Models are designed and built to solve a need.

Grade 3, Curriculum Framework, Overview (Page 3). Recommend adding: Designing and building models help develop solutions to problems.  
Essential Knowledge and Skills (Page 3). Recommend adding: Design and build a simple model to solve a problem.

Grade 3, 3.2 (Page 18). Recommend adding: (e) Designing and building simple machines to solve a need. [Note: This is already an Essential Skill in the Curriculum Framework.]

Grade 3, 3.11 (Page 19). Recommend expanding in framework to include new green technologies.

Grade 3, Curriculum Framework, Overview (Page 34). Essential Knowledge and Skills (Page 3). Recommend adding: Design an alternative energy solution to a problem

Grade 4, 4.1 (Page 20). Recommend modifying (l): models are constructed to clarify explanations, demonstrate relationships, and solve needs.

Grade 4, Curriculum Framework, Overview (Page 3). Recommend adding: Designing and building models help develop solutions to problems. Essential Knowledge and Skills (Page 3). Recommend adding: Design and build a simple model to solve a problem.

Grade 4, 4.10 (Page 22). Recommend expanding in framework to include impact of green technologies.

Grade 4, Curriculum Framework, 4.10 (Essential Knowledge and Skills). Add: Use Virginia resources to design an alternative energy solution to needs.

Grade 5, 5.1 (Page 23). Recommend adding: (j) Models are designed and built to meet a need.

Grade 5, Curriculum Framework, Overview (Page 3). Recommend adding: Designing and building models help develop solutions to problems. Essential Knowledge and Skills (Page 3). Recommend adding: Design and build a simple model to solve a problem.

Grade 5, 5.3 (Page 24). Recommend expanding in framework

Grade 5, Curriculum Framework, Overview (Page 9). Recommend adding: Light energy can be transformed into electrical energy to meet energy needs. Essential Knowledge and Skills. Recommend adding: Analyze the ability of solar panels to produce electricity.

Grade 6, 6.1 (Page 26). Recommend expanding in the framework: (i) models and simulations are used to illustrate and explain phenomena and systems

Grade 6 Curriculum Framework, Overview (Grade 6, Page 4). Recommend addition: Engineers use scientific principles and models to design and build products to meet needs.

LS.1 (Page 29). Comment: (d) models and simulations are constructed and used to illustrate and explain phenomena; suggest expanding in framework.

Life Science Curriculum Framework, Overview (Life Science, Page 2). Recommend addition: Engineers design and build models to balance human

and environmental needs.

PS.1 (Page 32). Recommend revision: (k) Research and engineering methods are used to investigate and resolve practical problems and questions.

PS.1 (Page 32). Recommend revision: (m) current applications of physical science concepts are used to design and build solutions to needs.

Physical Science Curriculum Framework, Overview (Physical Science, Page 4). Recommend addition: Engineering methods identify a problem or need and use scientific understanding and innovation to design and build a solution.

ES.1 (Page 35). Recommend revision: (f) current applications are used to reinforce Earth science concepts and design solutions to needs.

Earth Science Curriculum Framework, Essential Knowledge and Skills ( Earth Science, Page 3). Recommend addition: use engineering design methods to design and build solutions to need within the existing environment.

BIO.1 (Page 39). Recommend revision: (m) current applications are used to reinforce biological concepts and design solutions to needs.

Biology Curriculum Framework, Essential Understandings (Biology, Page 4). Recommend addition: Scientists and engineers look to nature for ideas to design and build solutions for needs.

CH.1 (Page 42). Recommend revision: (k) the use of current applications to reinforce chemistry concepts and design solutions to needs.

Chemistry Curriculum Framework, Essential Understandings (Chemistry, Page 6). Recommend addition: Chemical engineers use scientific concepts to design and build materials to meet needs.

PH.1 (Page 45). Recommend revision: (f) models are simulations and used to visualize and explain phenomena, to make predictions from hypotheses, to interpret data, and to design and build solutions to needs.

PH.1 (Page 45). Recommend addition: (g); the use of current applications to reinforce physics concepts to design and solutions to needs.

Physics Curriculum Framework, Essential Understandings (Physics, Page 2). Recommend addition: Engineers use physical laws to design and build solutions to needs.

Physics Curriculum Framework, Essential Knowledge and Skills (Physics, Page 2). Recommend addition: use design methods, models and simulations

to solve problems.

PH.4 (Page 46). Recommend that this be included in PH.1, as in other disciplines. If keep, then recommend revision: (b): exploration of the roles and contributions of science, engineering and technology.

PH.5 (Page 46). Recommend revision: The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical, experimental, and engineering processes.

PH.12 (Page 48). Recommend examination of objective set for where many of these concepts are already included and these concepts could be added. 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.

**7.0 Nanoscience. Recommend language such as the following in the Curriculum Framework to add detail to goals for integration of SMET and current applications. For each identified high school objective, recommendations are given for Essential Understandings (EU) and for Essential Knowledge & Skills (EK & S). For each identified middle school objective, recommendations are given for Overview and Essential Knowledge, Skills, and Processes (EK, S & P).**

**Physics**

PH.1 b

E.U. already stated

EK & S. Atomic Force microscopes and Scanning Tunneling Microscopes are essential instruments to determine properties and forces at the nanoscale.

PH.4 a

E.U. already stated

EK & S. Investigations into the photonic band gap are expanding the knowledge of and the ability to manipulate light, forces and matter.

PH.7 b (this is the new #7)

E. U. already stated

EK & S. Efficiency of nanosystems and work applications should be compared to those at the macroscale.

PH.10 b

E.U. already stated

EK & S. The nature of light includes a wave-particle duality.

Interactions between light and matter are an essential understanding of the band gap phenomena.

## **Chemistry**

### CH.1h

E. U. Describe the impact of new tools and instruments on increased understanding of nano, atomic and subatomic scales

EK&S. Explain how the use of atomic force and scanning probe microscopes, computer-based models, and simulations have revealed the unique properties of materials at the nanoscale.

### CH.2c

E. U. There are critical differences between the forces that impact matter as the size of particles approaches 100 nm or less.

EK & S. Explain the relative size and scale of matter and dominant forces at the macro, micro, nano, atomic, and subatomic levels. These forces include gravitational, electrical, and nuclear forces (strong and weak).

### CH. 3 d

E. U. The essence of bonding is involved in its electrical nature.

EK & S. Specific bonding types to be discussed are ionic, covalent, hydrogen and van der Waals forces.

### CH.3 e

E. U. Electron exchange is the driving force for the processes of oxidation and reduction.

EK & S. Identify oxidation numbers and the relationship between oxidation and reduction.

### CH. 3 f

E. U. There are several important factors that affect reaction rates and kinetics.

EK & S. One of these is the surface area/volume ratio.

### CH.5 c

E.U. already stated

EK & S. Phase changes depend on thermal energy, Brownian motion and the types of bonds present.

### CH. 6 a

E.U. A thorough understanding of organic chemistry begins with a study of the allotropes and bonding in carbon itself.

EK & S. Differentiate unique chemical and physical properties at the nanoscale for carbon's allotropes: graphite, diamond, fullerenes, and carbon nanotubes.

## **Biology**

BIO.1 i

E.U. Scientists now use a variety of microscopes to study living systems.

EK & S. Light microscopes assist in investigations dealing with organisms or samples on the micro scale and more powerful instruments are used to study samples on the nano scale.

BIO.3 e (Note: this is a new standard)

E.U. Although cells have some specialized structures, material transport is often accomplished randomly.

E K & S. Brownian motion is an essential process to move biological molecules.

BIO.4 e

E.U. Structure and function are affected by size and scale of the organism.

EK & S. As organisms' sizes become smaller viscosity and Brownian motion become the dominant forces.

BIO.5 g

E.U. already stated

EK & S. The synthesis of DNA and RNA involves the process called self assembly.

BIO.5 j

E.U. already stated

EK & S. DNA technologies involve the use of new imaging tools and nanoscale manipulation.

**Earth Science**

ES.1 c

EU: A complete study of Earth processes and cosmology requires an understanding of the size and scale of very large and very small items.

EK&S. Distances in space require very large measurements and the size of mineral particles require very small measurements that are often written in scientific notation.

EK& S. Cross-sections and three dimensional visualizations are essential tools for understanding geological processes.

ES.4 b

EU already stated

EK&S. Mineral dust on the earth's surface, in the hydrosphere, and in the atmosphere is an important component of rock-forming and earth processes.

ES.12 d

EU: Already stated.

EK& S. Mineral nanoparticles have an impact on geological processes and atmospheric quality.

ES.13 a

EU: An understanding of the size and scale of the components of the universe is a basis for the study of cosmology.

EK&S. There are different dominant forces operating at the various scales of masses in the universe.

## **Physical Science**

PS.1 m

Overview. Some of the more useful applications of physical science concepts are in the area of materials science.

EK, S & P. New discoveries based on nanoscience investigations have allowed the production of superior new materials with improved properties.

PS.2 b

Overview. Already stated.

EK, S & P. Different forms of elements called allotropes can exhibit a variety of properties.

PS.2 f

Overview. Already stated.

EK, S & P. Chemical and physical properties change as the size of the sample of matter approaches the nanoscale.

PS.4 c

Overview: Already stated.

EK,S & P. Both ionic and covalent bonds have an electrical nature.

PS. 5 b

Overview. Already stated

EK, S & P. Chemical changes are often affected by the surface area/volume ratio of the materials involved in the change.

PS. 9 e

Overview. Already stated.

EK, S & P. One application of light is the changes it affects in materials at the nanoscale.

## **Life Science**

LS.2 d

Overview: Already stated.

EK, S & P. Students will describe the impact of the surface area/volume ratio on cellular transport and cell division.

## **Science 6**

6.4 a

Overview: Already stated.

EK, S & P. Students will understand that all particles are in constant motion because of thermal energy.

**9.0 The MathScience Innovation Center is willing to provide staff to serve on various review committees related to Virginia's Standards of Learning and Curriculum Framework.**