Innovations and Implications of the NGSS

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The April 2013 release of the Next Generation Science Standards (NGSS) brings much excitement, and hopefully, productive stimulation to the science education community. As its name implies, the NGSS were preceded by the National Science Education Standards (NSES). Publication of the NSES (NRC, 1996) stimulated a wave of excitement in the science education community and positively influenced state-level standards, assessments, and curriculum materials. Significant advancements in science, science education, and technology have occurred since the introduction of NSES, and are now affecting our economy. Today, our nation needs a better and more efficient pathway for students entering science, technology, engineering, and mathematics (STEM) careers. Successful implementation of the NGSS has the potential to significantly improve the quality of science education in the United States. This article briefly discusses the most significant innovations in the NGSS and their implications for science teaching and learning, the influence of the NGSS on the development of instructional materials, and the need for professional development of both pre-service and in-service science teachers.

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Innovatively Integrated Design

Every standard in the NGSS is constructed on a three dimensional foundation: science and engineering practices, disciplinary core ideas (commonly referred to as content), and crosscutting concepts. Rather than being taught as separate entities, these dimensions are intertwined in a manner reflecting how scientists and engineers work in the real world. Arguably, the most significant innovation in NGSS is the inclusion of student performance expectations to demonstrate understanding of these "practices," "core ideas," and "crosscutting concepts." Thus, performance expectations are used to inform instruction as well as assessment. Most importantly, this integrated design is intended to inform the way units of instruction are organized, and the manner in which they are taught.

The architectural structure for each standard visually supports the intended integration of performance expectations, scientific and engineering practices, disciplinary core ideas, and crosscutting concepts. This unique organization provides an invaluable template for constructing coherent developmental sequences of lessons—an instructional materials developer's dream.

<table>
<tr><th colspan="3">5-ESS1 Earth's Place in the Universe</th></tr>
<tr><td colspan="3">Students who demonstrate understanding can:
5-ESS1-1. **Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from the Earth.** [Assessment Boundary: Assessment is limited to relative distances, not sizes, of stars. Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, stage).]</td></tr>
<tr><th>Science and Engineering Practices</th><th>Disciplinary Core Ideas</th><th>Crosscutting Concepts</th></tr>
<tr><td>**Engaging in Argument from Evidence**
Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).
• Support an argument with evidence, data, or a model.</td><td>**ESS1.A: The Universe and its Stars**
• The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.</td><td>**Scale, Proportion, and Quantity**
• Natural objects exist from the very small to the immensely large.</td></tr>
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Scientific and Engineering Practices

Scientists and engineers utilize a combination of knowledge and skills, referred to as practices in the NGSS, as they investigate and develop scientific explanations or design models and systems. These practices include: asking scientific questions, defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematical and computational thinking, constructing explanations from evidence, engaging in argument from evidence, and obtaining, evaluating, and communicating information.

The earlier NSES included separate content standards for Inquiry and for Science and Technology. This time around, the NGSS specifically emphasizes the integration of practice and content. In other words, the knowledgeable use of science and engineering practices enhances conceptual understanding of core ideas. Likewise, to become knowledgeable about practices, it is crucial that students learn the purpose, power, and limitations of specific practices in the context of the science content being studied.

Disciplinary Core Ideas

While ever expanding knowledge in science and engineering is exciting, it presents a complex problem for science education. K–12 students cannot be expected to remember, let alone understand, everything they see, hear, or read about the natural and designed world. Attempts to do so have produced science curricula, referred to as, “a mile wide and an inch deep.” Developers of the NGSS focused on a small coherent set of disciplinary core ideas in science and engineering. Armed with an understanding of a limited number of core principles, students will be better prepared to evaluate and make sense of new science and technology information. This set of core ideas includes fundamental concepts and principles in the life, Earth and space, and physical sciences, and engineering. They are also arranged in learning progressions to provide opportunities for students to construct, reinforce, and deepen their understandings along the K–12 learning path.

Crosscutting Concepts

You may recognize many of the crosscutting concepts as “common themes” from an earlier science education reform, Benchmarks for Science Literacy, by the American Association for the Advancement of Science (AAAS, 1993). Crosscutting concepts are broad conceptual ideas applied across the various disciplines of science. Seven such unifying ideas are identified in *A Framework for K–12 Science Education.* (NRC, 2012) They include: 1. Patterns; 2. Cause and effect: Mechanism and explanation; 3. Scale, proportion, and quantity; 4. Systems and system models; 5. Energy and matter: Flows, cycles, and conservation; 6. Structure and function; and 7. Stability and change. The NGSS stresses the interrelationships between crosscutting concepts and disciplinary core ideas. This implies that crosscutting concepts, for example Patterns, serve as context supporting the development of student understandings of the predictable motions of Sun, Moon, and stars—a disciplinary core idea. Consistent with the other two dimensions, the inclusion of crosscutting concepts is organized to support learning progressions from simple to more complex. Repeating developmental learning experiences and integrating the three NGSS dimensions will help students mold an understanding of, and appreciation for the nature of science.

So, where do we go from here? The innovations and challenges presented by the NGSS have numerous implications for classroom teachers, science supervisors, science educators, developers of instructional materials, and assessment specialists.

- The NGSS is not a curriculum. It is an integrated and well-articulated progression of goals reflecting what students should know and be able to do. The standards do not prescribe specific teaching methods. They do, however, provide a framework to inform science education in matters of teaching, learning, and assessment.

- Actively modeling and reflecting on the integration of practices and content must become a priority for professional development workshops. In these workshops teachers should be engaged in sequences of science lessons and assessments, developed from specific NGSS performance expectations, where they have opportunities to learn in roles both as students and as teachers.
- Science content courses for prospective elementary and middle school teachers should actively engage students in the integration of practices and content. NGSS scientific and engineering practices, core ideas, and crosscutting concepts, informed by expected student performances, should form the curriculum framework for science courses for pre-service teachers.
- While the NGSS do not suggest specific teaching methods and strategies, they do have implications for pedagogy. The emphasis on coherent progressions of learning outcomes, intertwining practices and content, requires flexible integrated classroom instruction. Teachers should be able to employ a variety of instructional methods promoting learning through inquiry. Instructional models, including the widely accepted 5E learning cycle model, allow for flexibility, coherence, and effective use of classroom time.
- The development of curriculum materials, consistent with the goals and intent of the NGSS is imperative. The national impact of the NGSS will become significantly diluted and ineffective unless teachers have ready access to NGSS based curriculum materials. “Curriculum materials will be the missing link if they are not developed and implemented. The absence of a curriculum based on the new standards will be a major failure in this era of standards-based reform and assessment-dominated results.” (Bybee, 2013, p. 7)
- Those involved in modifying existing instructional materials or developing new materials must focus on coherent sequences of integrated learning experiences to help students demonstrate the full range of performance expectations for a single grade level standard.
- Adoption commitments from a large cross section of the states are critical if we are to witness significant improvement in the quality of science curriculum and instruction nationally.

Is the science education community up to the challenge? Only time will tell.

References:
American Association for the Advancement of Science (AAAS). (1993). Benchmarks for science literacy. New York: Oxford University Press.

Bybee, R. W. (2013). The next generation science standards and the life sciences. Science and Children 50 (6): 7-14.

National Research Council (NRC). (1996). National science education standards. Washington, DC: The National Academies Press.

National Research Council (NRC). (2012). A framework for K–12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: The National Academies Press.

NGSS Lead States. 2013. Next generation science standards: For states, by states. Washington, DC: National Academies Press.