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Implications for Earth and Space in New K–12 Science Standards

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New science standards for national K–12 science education are in the process of being written by a states-led team of writers organized by Achieve, Inc., with important implications for teaching Earth and space sciences. The final version of these "Next Generation Science Standards" (NGSS) is scheduled to be released in early 2013, but a second draft of the standards will be made public in December 2012. Members of the Earth and space science (ESS) research communities can review this draft of NGSS and provide constructive feedback. Such feedback will help ensure that American students receive instruction that is accurate, relevant, and engaging.

The United States does not currently have national K–12 science education standards. Each state determines its own standards and its own assessments, reflecting the tradition of independent states' rights. However, NGSS are being offered during a time of greater willingness by states to adopt national standards. Further, the standards represent a departure from traditional science standards in that they are designed to assess what students can do and not just what they know.

Science Standards in the Context of Current Curricula

Primary and secondary school science curricula vary greatly among (and often within) states. This has obvious drawbacks for students who move between schools, especially during their K–8 years. This also provides significant challenges for college and career readiness (CCR); companies hiring for jobs related to science, technology, engineering, and mathematics (STEM) face extreme inconsistency in the educational backgrounds of their employees. Introductory university courses must also accommodate extreme variation in the quality of students' high school classes.

This discrepancy in curricula can be seen in national assessments such as the 2011 National Assessment of Educational Progress (NAEP) test results. For example, in the standardized NAEP 8th grade science assessment, 45% of students in North Dakota tested as being "proficient" or "advanced," compared to just 18% for Mississippi and 8% for the District of Columbia [*National Center for Education Statistics,* 2012].

In high school, the number of required years of science also varies greatly among states. As of 2008, 31 states required 3 or 4 years of high school science (up from a total of 10 states in 1996) [*National Science Board*, 2012]. However, having 3 years of high school science usually means biology, physics, and chemistry, with Earth Science available as an alternative for those students less interested in science. This is an antiquated holdover from the 1893 "Committee of Ten" report, which suggested that "physical geography" be taught before the 3 years of biology, physics, and chemistry [*National Education Association*, 1893]. There are very few states where Earth science is a required part of the high school curriculum [*Blank et al.*, 2007]; the lack of ESS education is exacerbated by the reluctance of the U.S. College Board to create an ESS Advanced Placement test. The geosciences are as rigorous and sophisticated as any other science at the university level, but there are few mechanisms by which high school students would know this.

Outlook for Adopting NGSS

In this context of the previous reluctance of states to adopt a common set of science standards and the noticeable absence of substantial Earth and space sciences from most high school curricula, it would be easy to be pessimistic about the potential impact of NGSS on K–12 ESS education. For example, both the National Science Education Standards [*National Research Council* (*NRC*), 1996] and American Association for the Advancement of Science (AAAS) Benchmarks [*AAAS*, 1993] had substantial amounts of high school ESS content. However, there are good reasons to be optimistic about the new NGSS science standards being adopted by many states, and therefore of an increased ESS emphasis. This results from two factors: a greater willingness by

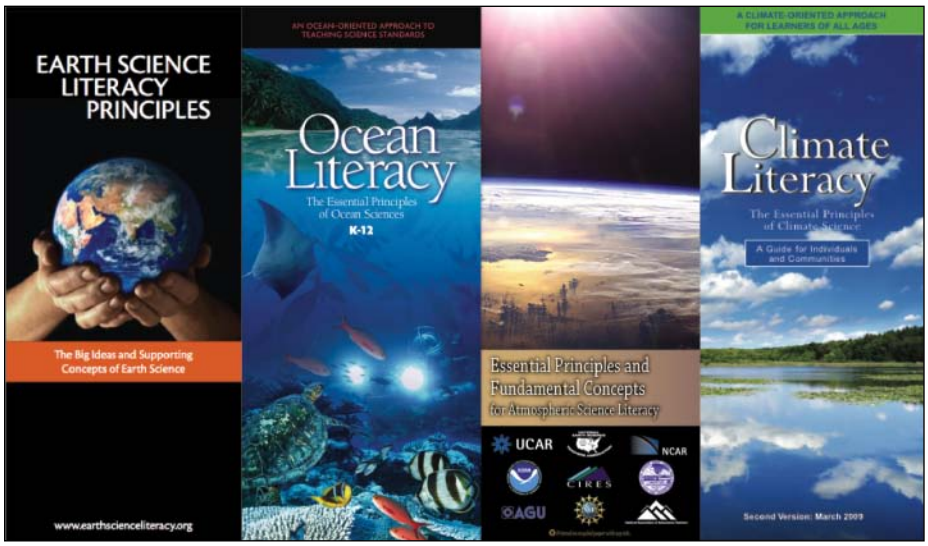

Fig. 1. The covers of the four community literacy documents that influenced the Earth and space science content of the National Research Council's A Framework for K–12 Science Education *[*NRC, *2011] and therefore the writing of the first draft of the Next Generation Science Standards. From left to right: courtesy of the U.S. National Science Foundation (NSF), the U.S. National Oceanic and Atmospheric Administration (NOAA), NSF, and NOAA.*

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states to adopt national standards and the way that NGSS are being constructed.

Most of the states (45) and three territories are in the process of adopting the "Common Core" curriculum for math and English language arts, which were written by the organization Achieve, Inc. (see http://www.achieve.org/next-generation-science-standards). States were encouraged to adopt this national curriculum through the "Race to the Top" competition, whereby federal funds were awarded to states that demonstrated substantial improvement in math and English language arts education. There is increasing attention being paid to STEM education because of the mediocre performance of U.S. students compared to other nations in a global economy that is shifting toward a more technology-oriented workforce. For example, in the 2009 Programme for International Student Assessment (PISA) test of international 15-year-olds from 74 participating nations and territories, the United States ranked 23rd in science and 31st in math [*OECD*, 2012]. Increased attention to STEM education also comes from industries encouraging their home states to improve K–12 science and engineering education so that their local workforce will be competent enough to meet the growing demand for technology-related jobs.

Many states also appreciate that these standards are the result of a state-led process and not a federal one. The development of NGSS is funded by the Carnegie Foundation of New York, with no federal funding. And though the writing of the standards is being supervised by the same organization (Achieve, Inc.) that wrote the common core math and English standards [*National Governors Association Center for Best Practices, Council of Chief State School Officers*, 2010], the process has been structured very differently: 26 participating states representing more than half the nation's children are closely involved with the writing. More than 40 professionals are on the NGSS writing team, working closely with educational leaders from these 26 states to ensure that the standards are constructed in ways that will meet states' needs.

Comparison of Earth and Space Science Broad Topics for the *National Research Council's* [2011] *A Framework for K–12 Science Education* and the First Draft of the Next Generation Science Standards

Framework for K–12 Science Education

Earth's Place in the Universe
- The Universe and its Stars
- Earth and the Solar System
- The History of Planet Earth

Earth's Systems
- Earth Materials and Systems
- Plate Tectonics and Large-Scale System Interactions
- The Roles of Water in Earth's Surface Processes
- Weather and Climate
- Biogeology

Human Interactions
- Natural Hazards
- Natural Resources
- Human Impacts on Earth Systems
- Global Climate Change

Next Generation Science Standards: Middle School (Draft, May, 2012)
- Space Systems
- History of Earth
- Earth's Interior Processes
- Earth's Surface Processes
- Weather and Climate
- Human Impacts

Next Generation Science Standards: High School (Draft, May, 2012)
- Space Systems
- History of Earth
- Earth's Systems
- Climate Change
- Human Sustainability

ESS in the Context of the NGSS Framework

The scientific credentials for NGSS come from a two-step process that began with the writing of the National Research Council (NRC) report *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* also funded by the Carnegie Foundation of New York [*NRC*, 2011]. This NRC framework laid the foundation for the development of modern science standards by incorporating current research in the major science and engineering disciplines as well as in cognitive science and educational learning progressions [*NRC*, 2007, 2008]. The framework established a three-dimensional approach to standards that weaves together disciplinary core ideas, science and engineering practices, and big-picture crosscutting concepts. NGSS represent the expression of this framework, writing out the actual standards based on this three-dimensional approach. Three scientific groups were given equal stature in the process (life science, physical science, and Earth and space sciences), with the distinction between physics and chemistry significantly downplayed. In addition, the standards incorporate a new emphasis: engineering, technology, and applications of science. The content of these four areas was largely determined by four corresponding design teams.

The Earth and Space Sciences Design Team, consisting of Michael Wysession (chair, Washington University in St. Louis), Don Duggan-Haas (Paleontological Research Institute), Scott Linneman (Western Washington University), Eric Pyle (James Madison University), and Dennis Schatz (Pacific Science Center), was able to draw upon several recent community efforts that constructed field-specific literacy documents. One such effort is the Earth Science Literacy Principles [*Wysession et al.*, 2012] (http://www.earthscienceliteracy.org), which consist of the nine "Big Ideas" and 75 "Supporting Concepts" that establish the essential understanding that every citizen should have about Earth science. It was drafted with direct input from 350 Earth scientists and educators and reviewed by many hundreds more. In addition, the Essential Principles of Ocean Literacy (http://www.coexploration.org/oceanliteracy/documents/OceanLitChart.pdf), Essential Principles and Fundamental Concepts for Atmospheric Science Literacy (http://eo.ucar.edu/asl/index.html), and Essential Principles of Climate Science (http://cleanet.org/cln/index.html) literacy documents were constructed by similar community-driven efforts. These literacy frameworks (see Figure 1) strongly influenced the ESS content of the NRC Framework, although the Framework directly reflects neither the community literacy documents nor the recommendations of the ESS Design Team but was ultimately constructed by only the NRC Committee.

The new NGSS represent a departure from traditional science standards in that they are designed to assess what students can do and not just what they know. Of the three strands, the disciplinary core ideas are the "what" of the standards and the practices are the "how." The crosscutting concepts are big themes of science, like patterns, cause and effect, scale and proportion, and matter and energy, which are key to all the fields of science. NGSS themselves are presented as a set of performance expectations that complete the sentence "Students who demonstrate understanding can…" by combining a single disciplinary core idea with a single practice and a single crosscutting concept. For example, in the first draft of the middle school standard topic on Earth's interior processes, one particular performance expectation reads, "Students who demonstrate understanding can use models to explain how the flow of energy drives a cycling of matter between Earth's surface and deep interior." The content comes from the NRC Framework's 6–8 grade-band endpoints, but the selected practice to go with this is "Developing and Using Models," and the associated crosscutting concept is "Energy and Matter: Flows, Cycles, and Conservation."

ESS Content in Detail

The NRC Framework distributed the ESS content across three "Big Ideas" (see box), partitioned differently at the elementary, middle, and high school levels. At the elementary (K–5) level the standards are fully integrated across all of the science and engineering disciplines, but in middle and high school the standards are presented separately by field. The three ESS Big Ideas

of the NRC Framework are distributed across six topics for middle school and five for high school in the new NGSS.

There are several notable aspects to the ESS standards in the first draft of NGSS, released in May (http://www.nextgenscience.org/next-generation-science-standards). The amount of high school ESS content is on a par with chemistry, physics, and biology. The number of ESS middle school performance expectations was nearly identical to those for both life science and physical science for middle school, and the number of ESS high school performance expectations was the same as that of life science and two thirds of that of physical science. The National Science Education Standards had many high school ESS standards [*NRC*, 1996], but without the existence of national standards, states could disregard these recommendations with no ramifications. However, if states adopt the new NGSS, they will need to adopt them in their entirety, which means that there will be motivation to incorporate the increased high school ESS content.

Other notable changes in how ESS is represented in the NGSS draft compared to the previous education standards relate to shifts of content emphasis. There is a greater emphasis on an Earth-systems approach, which reflects a growing awareness not only of the interconnectedness of Earth's different spheres but also of an increase in interdisciplinary ESS research. Human-related content is now incorporated directly into the ESS standards (middle school "Human Impacts" and high school "Human Sustainability"), as opposed to being a separate set of standards. This reflects a continually increasing awareness of the enormous impact of human activities on all of Earth's surface systems and of the increasingly critical role that natural hazards and resource availability play in human society as populations, industrialization, and urbanization increase. Last, there is an increased emphasis on climate and climate change, which reflects not only the overwhelming community consensus on the significant role that humans play in altering climates on a global scale but also the increasing understanding of the complexity of the multiple factors involved with climate change over many different time scales and the significant impacts that the history of climate change has had on the evolution of life and the development of human civilization [*NRC*, 2010].

An Opportunity for Input

The Next Generation Science Standards are not final. The second public draft is due to be released by Achieve in December 2012 and will be available at http://www.nextgenscience.org/. All concerned Earth and space scientists are urged to review this draft and provide their input to help ensure that these standards best represent the current community understandings. In particular, input on the accuracy and relevancy of these performance expectations would be greatly appreciated.

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Author Information

Michael E. Wysession, Department of Earth and Planetary Sciences, Washington University in St. Louis, St. Louis, Mo.; E-mail: michael@wucore.wustl.edu.

Wysession is on the organizing committee that is guiding the writing of the Next Generation Science Standards.