Preparing Future Secondary Science Teachers for the Next Generation Science Standards

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In this brief, we provide an overview of the development of A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas *and the Next Generation Science Standards. We explore the implications for teacher preparation and suggest recommendations for universities.*

A broad scale re-evaluation of how to better help students learn science is benefiting from the momentum generated by the state-led Common Core State Standards for English Language Arts and for Mathematics. States, K-12 schools and districts, higher education, business and industry, and other critical stakeholders across the country are mobilizing behind the evidence that all young people need to have a strong foundation in science, engineering, and mathematics to succeed in the workplace and to lead fulfilling lives.

With the release of *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*[1], the National Research Council (NRC) has articulated a new vision for science and engineering education that lays the foundation for what all students should know and be able to do in the sciences to be college and career ready[2]. This Framework is the first step for the state-led process, now underway and described below, to develop the Next Generation Science Standards (NGSS).

At A·P·L·U's Science and Mathematics Teacher Imperative (SMTI), we are struck by the implications for science teacher preparation embedded in the science framework and that will be required for successful implementation of the NGSS. The NGSS will require teachers to think scientifically, to engage in more project-based learning with their students using relevant problems, and to inspire and facilitate students to engage in scientific and engineering practices. New and experienced teachers will require additional training to teach to the NGSS. Such training will require strengthened partnerships between schools of education, disciplinary departments at institutions of higher education, and school districts. As stated in the American Council on Education report *To Touch the Future: Transforming the Way Teachers Are Taught*[3] and in the APLU/SMTI report *The Common Core State Standards and Teacher Preparation*[4], teacher preparation takes the whole university.

A Framework for K-12 Science Education

The Framework was written by an 18-member panel of researchers, including two Nobel laureates, science education researchers, cognitive scientists, and science education standards and policy experts convened by the National Academies. After 18 months of deliberation and opportunities for public comment, *A Framework for K-12 Science Education*, was released in July 2011. Four disciplinary teams helped develop the discipline specific content for the physical sciences (physics and chemistry), the life sciences, earth and space science, and engineering and technology. The Framework is evidence-based, draws from current research on teaching and learning, and is informed by the NRC's *National Science Education Standards*[5], AAAS's *Benchmarks for Science Literacy*[6], and benchmarks to international standards[7]. There are parallels between the Common Core State Standards for mathematics and A *Framework for K-12 Science Education*—the most obvious linkages being the practices of using mathematical and computational thinking, and

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obtaining, evaluating, and communicating information.

The Framework has three dimensions that are intended to be integrated into new science standards, assessments and curricula. The first dimension is eight **Scientific and Engineering Practices**[8] that all students should be able to demonstrate. The second dimension identifies seven **Cross-Cutting Concepts** that serve as a framework for connecting knowledge across the disciplines to help students form a coherent and scientifically based understanding of the world. The third dimension, **Disciplinary Core Ideas**, is a limited set of ideas designed to allow for an increasing depth of core knowledge over time. The core ideas are important for understanding the discipline and have real-world relevance to encourage engagement with the scientific or engineering concept.

Next Generation Science Standards

Developing the Framework was the first step in rethinking K-12 science and engineering education. The next step is developing the Next Generation Science Standards (NGSS) to provide the specificity, integration, and coherence needed to bring this vision to the classroom, and thus ensure all students have a relevant K-12 science education. The National Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, and Achieve have embarked on a two-step process to develop the NGSS. In a process managed by Achieve, twenty-six states will lead the development of K–12 science standards that are rigorous, internationally-benchmarked, and build upon the results of research on learning and teaching[9].

Three Dimensions of the Framework

Scientific and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

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
7. Stability and change

Disciplinary Core Ideas

Physical Sciences

- PS 1: Matter and its interactions
- PS 2: Motion and stability: Forces and interactions
- PS 3: Energy
- PS 4: Waves and their applications in technologies for information transfer

Life Sciences

- LS 1: From molecules to organisms: Structures and processes
- LS 2: Ecosystems: Interactions, energy, and dynamics
- LS 3: Heredity: Inheritance and variation of traits
- LS 4: Biological evolution: Unity and diversity

Earth and Space Sciences

- ESS 1: Earth's place in the universe
- ESS 2: Earth's systems
- ESS 3: Earth and human activity

Engineering, Technology, and the Applications of Science

- ETS 1: Engineering design
- ETS 2: Links among engineering, technology, science, and society

The NGSS will integrate the core disciplinary ideas, scientific and engineering practices, and cross-cutting concepts and will be released in the fall 2012. States will choose whether or not to adopt these standards and align new assessments to them.

The NGSS Timeline

- Summer 2011: Lead states and writers[10] were chosen;
- Winter 2012: States receive draft; states provide feedback; and writing team revises the draft standards;
- Spring 2012: Public draft released; critical stakeholders and public provide feedback; and writing team revises;
- Spring 2012: Second state draft (and critical stakeholders) released; writing team revises
- Summer–Fall 2012: Second public draft released;
- Fall 2012: Writing team revises;
- Fall 2012: Final draft to states for comment;
- Fall 2012: Writing team reacts to final review;
- Fall 2012: Achieve edits final document and releases the NGSS.

Preparing Secondary Science Teachers for NGSS

The NGSS will require a new way of educating teachers. SMTI's members, who prepare 8,000 new science and mathematics teachers for middle and high school each year, can help support the implementation of the standards by focusing on preparing these new teachers. Teacher preparation programs can ensure that newly prepared science teachers are well versed in both the practices and cross-cutting concepts, and their import for teaching science. They can also ensure that new teachers have their disciplinary knowledge augmented by discipline-specific pedagogical knowledge, which is critical for teaching the scientific discipline effectively.

As we stated in an earlier publication[11], "Teachers will need to know the standards; they will need the background content knowledge and the professional commitment to teach the standards to students; and they will need to have mastered instructional strategies that help them assist students of all abilities and ages in attaining much higher standards than have previously been in place." This will require strengthened partnerships between schools of education and disciplinary departments at institutions of higher education. As noted recently by a renowned chemist, "disciplinary societies, such as ACS [American Chemical Society], can help build awareness of both the framework and standards within their own communities, define what the documents mean for teachers using the standards within a disciplinary context, and help translate the NGSS into practice." [12]

The disciplinary departments also play a vital role in modeling good science teaching in undergraduate science courses since this is where future science teachers see science teaching. Teachers need to have experience with the practices of science in order to be able to incorporate them into their classrooms with confidence and fidelity. Efforts undertaken by the Association of American Universities (AAU)[13] and highlighted in a recent report by the President's Council of Advisors on Science and Technology[14] are key to this transformation of undergraduate science teaching.

To address the connection between higher education and the NGSS, APLU/SMTI held a meeting in the fall with disciplinary societies, associations of higher education, Achieve, the National Academies, the National Science Foundation, and scientists like Dr. Helen Quinn, Chair of the NRC's Framework Committee. We will hold follow-up meetings in the spring of 2012, along with programming on the NGSS at the SMTI National Conference on June 6-8, 2012 in Washington, DC.

SMTI has begun parallel efforts to help support teacher preparation for the Common Core State Standards for Mathematics. To learn more about this project, the Mathematics Teacher Education Partnership (MTE-Partnership), visit www.aplu.org/MTE-Partnership.

To find out how you can be involved in SMTI, contact Kacy Redd at kredd@aplu.org.

APLU—the nation's public research universities—launched the Science and Mathematics Teacher Imperative (SMTI), to transform middle and high school STEM education by preparing a new generation of world-class science and mathematics teachers. SMTI has grown to include 131 public research universities—including 13 university systems--across 44 states. Collectively, SMTI members prepare more than 8,000 science and mathematics teachers annually—making it the largest STEM new teacher initiative in the country.

What you can do as a university faculty member or institutional leader

1. Become familiar with the NRC's Framework: http://www7.nationalacademies.org/bose/Standards_Framework_Homepage.html.
2. Become involved in state-level discussions by contacting your state NGSS liaison to inquire how your institution can participate in the development of the standards (http://www.nextgenscience.org/lead-state-partners).
3. Raise awareness of the NGSS with the university president, provost, deans, department chairs, and fellow faculty.
4. Build a coalition on campus to engage the multiple units across disciplinary departments and teacher education departments to consider their responsibility in responding to the NGSS, including if the science teacher preparation program is preparing teachers to meet the demands of the NGSS.
5. Build coalitions with institutions of higher education across the state to grow support for the NGSS, ensure a commonality of vision, and develop shared resources for responding to the NGSS.
6. Build collaborative relationships with K-12 leaders to discuss shared implications of the NGSS and opportunities to leverage resources.
7. Become involved with A·P·L·U's Science and Mathematics Teacher Imperative and disciplinary societies who are working on meeting the demands of the NGSS.

Additional Resources

- Next Generation Science Standards website at http://www.nextgenscience.org/.
- National Science Teachers Association website at http://www.nsta.org/about/standardsupdate/default.aspx.
- Science and Mathematics Teacher Imperative website at http://www.aplu.org/SMTI.

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Notes

1. National Research Council, "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas," 2011, Washington, DC: The National Academies Press < http://www.nap.edu/catalog.php?record_id=13165>
2. For a more detailed description the Framework, see Helen Quinn, "A Framework for K-12 Science Education," (APS News, November, 2011), Volume 20, No.10 <http://www.aps.org/publications/apsnews/201111/backpage.cfm>
3. American Council on Education, "To Touch the Future: Transforming the Way Teachers Are Taught," 1999 <http://www.acenet.edu/bookstore/pdf/teacher-ed-rpt.pdf>
4. Association of Public and Land-grant Universities, "The Common Core State Standards and Teacher Preparation: The Role for Higher Education," SMTI/TLC Working Group on CCSS, October 2011 <Available: http://www.aplu.org/document.doc?id=3482>
5. National Research Council, "National Science Education Standards," 1996, National Committee for Science Education Standards and Assessment. Washington, DC: National Academy Press.
6. American Association for the Advancement of Science, "Benchmarks for Science Literacy," 2009, Project 2061 <http://www.project2061.org/publications/bsl/online/index.php?home=true>
7. Achieve, "International Science Benchmarking Report," September 2011 <http://www.achieve.org/international-science-benchmarking-report>
8. For more information about the practices, see Rodger Bybee, "Scientific and Engineering Practices in K-12 Classrooms," December 2011 <http://www.nsta.org/about/standardsupdate/resources/201112_Framework-Bybee.pdf>
9. For more information about the research on learning and teaching, visit http://www.nextgenscience.org/standards-background-research-and-reports.
10. For a list of the lead states involved in the NGSS, visit http://www.nextgenscience.org/lead-state-partners. For the NGSS writers, visit http://www.nextgenscience.org/writing-team.
11. APLU, loc. cit, p. 3.
12. George M. Bodner, "Preparing Chemistry Teachers for the Next Generation Science Standards," Chemical and Engineering News, December 2011, Vol 89, Issue 50 <http://cen.acs.org/articles/89/i50/Preparing-Chemistry-Teachers-Next-Generation.html>
13. For more information about AAU's five year initiative to improve the quality of undergraduate teaching and learning in science, visit http://www.aau.edu/policy/article.aspx?id=12588.
14. President's Council of Advisors on Science and Technology, "Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics," February 2012 <http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf>