Implementing the *Next Generation Science Standards:*

Strategies for Educational Leaders

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Abstract

The *Next Generation Science Standards* embody a bold new vision for science education, grounded in the idea that science is both a body of knowledge and a set of linked practices for developing knowledge. In this article, we describe strategies that school and district leaders should consider when designing strategies to support *NGSS* implementation. Our recommendations draw both on past research on standards implementation and on a recently concluded study that examined the impacts of curriculum and professional development on student learning.

Introduction

The *Next Generation Science Standards* (NGSS; National Research Council, 2013c) present an unprecedented opportunity to transform science education for all students. Where past standards separated content from process, the *NGSS* expect students to develop an integrated understanding of science both as a body of knowledge and a set of practices for developing new knowledge. In addition, students are expected to apply crosscutting concepts that unify science and engineering—concepts like structure and function, cause and effect—to deepen their understanding of those core ideas. Every single performance expectation for students in the NGSS reflects this integrated, "three-dimensional" view of what it means to learn science.

These standards are distinctive for another reason, in that state education agencies and stakeholders in science education developed them using a National Research Council (2012) consensus report, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* The *Framework*, written by a committee of prominent scientists, science educators, education researchers, and state leaders to guide the development of the new standards, sought to build upon the foundation of the first generation of science standards documents, but also called for developing standards around a few core ideas that students would revisit over multiple school years. The *Framework* also called for a sharper focus on equity and diversity in science education. All students should be expected to reach high academic standards and also have adequate opportunities to learn science. Science educators should identify interests, experiences, and cultural practices relevant to young people's everyday lives, and instruction should make use of these to support science learning.

There is energy and excitement behind the *NGSS* in the science education community. The development process, facilitated by Achieve, Inc., involved 26 lead states, 41 writers, and hundreds of science teachers, scientists and engineers, education researchers who provided feedback on drafts, helping build momentum and support. Already, 11 states and the District of Columbia representing 26% of the student population in the U.S. have adopted the *NGSS,* and more are likely to follow. Science leaders across the country have embraced the vision of the *Framework,* whether or not their states are planning for adoption of *NGSS.*

Implementing the vision of the *Framework* and *NGSS* will not be easy. At present, few schools have access to curriculum materials that are even partly aligned to the *Framework*'s vision. Such materials are especially rare in schools that serve low-income students and students from groups that are underrepresented in science and engineering fields. The *Framework* calls for big shifts in teaching that will require extensive professional development. At present, few teachers engage students in practices that require more intensive student discussion but that are essential to the *Framework,* practices such as developing and using models, constructing explanations, and engaging in argument from evidence. In addition, there are few assessments that measure the three-dimensional performance expectations of the *NGSS*. Finally, too few students are exposed to rich science instruction in elementary school, which compromises the goal of building a rich understanding of science among all students across their K-12 careers.

Pursuing Research-Based Strategies for Implementation

Though the *NGSS* are new, there is research evidence that state, district, and school leaders can use to inform implementation planning. More than a decade of policy research on standards implementation in reading, mathematics, and science education has yielded important insights about what educational decision makers can do to support improvements to teaching and learning.

Provide high-quality curriculum materials to teachers and students. A key finding from standards implementation research is that curriculum materials matter. Whether teachers adopt, adapt, or design curriculum materials, those materials matter because they are how students encounter the standards. High-quality materials provide models for how to help students meet challenging learning goals in standards, and they provide tools to help teachers improve their practice (Davis & Krajcik, 2005). In science, materials also include the tools needed for students to actually do science—lab equipment, for example—and these must be accessible to all students in all schools. A new rubric for judging the quality of materials for *NGSS* is now available for leaders to use (http://tinyurl.com/ny9s4ej).

We recently concluded an evaluation study of research-based science curriculum materials designed to support integrated science teaching and learning. There is no single set of materials today aligned to the *NGSS*, though some integrate the science and engineering practices that get greater emphasis in the new standards than in the first generation of standards, such as explanation and developing and using models. The *Project-Based Inquiry Science (PBIS)* curriculum units that were the focus of our study are one such example. Developed with support from the National Science Foundation by a team of science content experts and learning scientists, *PBIS* is among the first widely available materials that reflect what we know about how students learn science. Our initial study found positive impacts on teaching and learning for all subgroups of students. The study took place within a large urban district with high percentages of low-income students and students from underrepresented groups.

Provide professional development that is focused on performance expectations for students, linked to classroom teaching, and sustained over time. Professional development was a critical support for implementing the first generation of science education standards. The kind of professional development that made a difference to teachers' instruction was focused on core science content, gave them strategies for engaging in more student-centered teaching, and was sustained over time (Garet, Porter, Desimone, Birman, & Yoon, 2001; Supovitz & Turner, 2000). Particularly effective strategies documented through rigorous studies include supporting teachers in analyzing their own practice and student work with colleagues (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Roth et al., 2011) and preparing teachers to adapt high-quality instructional materials (Penuel, Gallagher, & Moorthy, 2011).

In our PBIS study, professional development conducted over multiple sessions throughout the two years of the study focused intensively on aspects of the *Framework* that represent significant departures from most teachers' typical instruction. We provided teachers with both images and experiences of three-dimensional science learning. For example, teachers had to construct, share, and revise models that explain why you can compress and expand air in a syringe. As part of the activity, the teachers experimented with syringes, and they made drawings that depicted things they couldn't see (the motion of particles inside the syringe) to account for what happens when the syringe is pulled back, pushed, and pushed when the open tip is closed. The activity was designed to help teachers understand that air is made of "stuff" (part of the core idea, PS-1, Matter and its Interactions) and also to help them gain experience with how cycles of developing and sharing models, conducting investigations, and revising models to account for all the evidence in ways that respond to peer critiques are integral to science learning. Teachers also learned about the nature of models of systems, a key crosscutting concept.

Monitor and support implementation. When standards-based reforms are introduced into schools and districts, teachers and educational leaders have to continually adapt them as those reforms begin to change day-to-day practices (Weinbaum & Supovitz, 2010). Educational leaders especially need data on implementation, in order to know whether and how reforms are taking hold in their school and to design better supports for implementation. Recent reports (National Research Council, 2013a, 2013b) conclude that assessing students' opportunities to learn science are critical for systems, especially to promote equity of opportunity to learn.

In our *PBIS* study, we monitored and supported teachers' implementation in several key ways. Teachers completed instructional logs, which told study leaders and coaches for teachers how far into the unit teachers were at a given time point and what opportunities were allotted to students to engage in science practices. For a sample of teachers, we also collected evidence from video records of their practice and samples of assignments and associated student work. We also worked closely with a coach in the district to identify challenges teachers reported as they implemented the materials with students, which helped us to adjust professional development plans and ensure teachers had the needed supplies to implement investigations with students.

Develop and use assessments that measure knowledge-in-use. At present, there are few tasks that assess how students apply disciplinary core ideas and crosscutting concepts through science practices. Teachers will need to develop tasks that strategically diagnose student progress toward proficiency on the *NGSS* and to inform their instruction and lesson designs. Districts will need to develop a system of assessments for monitoring and improving classroom learning, because no single assessment can measure all the performance expectations for any given grade level (National Research Council, 2013a). This is important, because when states began to use tests to monitor progress on prior standards, those tests did have a big impact, though not always what was intended. Only in states where the content tested reflected challenging learning goals for students did teaching shift in ways that fostered deeper student learning (Au, 2007).

In the *PBIS* study, we had to develop and test new assessments that could measure next generation science learning goals. We followed a process called "Evidence Centered Design," a principled approach to writing tasks, piloting them, and revising them based on evidence of student performance. Our tasks made two science practices focal: constructing explanations and developing and using models. Every open-ended task on our assessments required students to demonstrate understanding of a disciplinary core idea by engaging in one of those two practices. The tasks looked very different from traditional test items that primarily test for recall (Figure 1). The rubrics developed for each of these tasks integrated a disciplinary core idea, a practice, and a crosscutting concept. Our pilot tests showed we could reliably score these items and that they were sensitive to instruction, two key criteria for validity in assessments.

Insert Figure 1 about here

Treat implementation as presenting learning opportunities for everyone in the system. Implementing the *NGSS* will demand significant changes for everyone in schools and districts, from students to teachers to school and district leaders. All too often, though, we forget that implementing new standards requires purposeful design of learning opportunities for everyone in the system to develop an understanding of the standards and knowledge of the changes that will be required for curriculum, assessment, and professional development. Teachers and leaders will also have to learn on the fly, as they invent new strategies to address challenges that arise with implementation. Implementing the *NGSS* will be easier if we think of teachers and leaders as co-learners, instead of demanding compliance to specific indicators of standards that few people understand well.

In the *PBIS* study, we encountered a challenge with principals of teachers trying to implement the PBIS curriculum. Some principals interpreted teachers' instructional strategies as inconsistent with what new state evaluation guidelines indicated was good teaching. Teachers understandably were concerned that their jobs were in jeopardy. To assist principals in learning about the implications of the *Framework* for science instruction, our study team quickly developed a guide that could help principals see connections between the state-required observation protocol and the *Framework.* Teachers found this tool especially helpful, as they thought it could help facilitate conversations with their principal not only about the study but also about good science teaching.

Sustaining the Changes Demanded by the *Framework* and *NGSS*

Multiple organizations are working to support implementation of the vision of the *Framework* and meeting the ambitious performance expectations of *NGSS.* These include organizations of leaders in states and districts, professional organizations for science teachers, intermediary organizations, and business groups. They are not only developing resources for teachers and educational leaders, they are also supporting planning for the long-term, that is, for how to sustain the kinds of changes demanded by the *Framework* and *NGSS*.

Educational leaders can play a key role in building an infrastructure for developing and sustaining improvements to science education in the long-term. They can advocate for sustained professional development, identify resources to support building-level teacher teams, and develop curriculum selection and adaptation processes that simultaneously build understanding of NGSS and capacity to implement the standards. Educational leaders are essential, too, for realizing the vision of science for all, by promoting strategies and identifying resources for equitable access to powerful science learning opportunities and equitable participation in science classrooms. Together, we can and must create a new, more equitable system of science education in which all students are prepared to do science and use science to make their communities better places to live for the future.

References

Au, W. (2007). High-stakes testing and curricular control: A qualitative metasynthesis. *Educational Researcher, 36*(5), 258-267.

Davis, E. A., & Krajcik, J. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher, 34*(3), 3-14.

Garet, M. S., Porter, A. C., Desimone, L. M., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915-945.

Heller, J. I., Daehler, K. R., Wong, N., Shinohara, M., & Miratrix, L. W. (2012). Differential effects of three professional development models on teacher knowledge and student achievement in elementary science. *Journal of Research in Science Teaching, 49*(3), 333-362.

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

National Research Council. (2013a). Developing assessments for the Next Generation Science Standards. Washington, DC: National Academies Press.

National Research Council. (2013b). Monitoring progress toward successful STEM education: A nation advancing? Washington, DC: National Academies Press.

National Research Council. (2013c). Next Generation Science Standards: For states, by states. Washington, DC: National Academies Press.

Penuel, W. R., Gallagher, L. P., & Moorthy, S. (2011). Preparing teachers to design sequences of instruction in Earth science: A comparison of three professional development programs. *American Educational Research Journal, 48*(4), 996-1025.

Roth, K. J., Garnier, H. E., Chen, C., Lemmens, M., Schwille, K., & Wickler, N. I. Z. (2011). Videobased lesson analysis: Effective PD for teacher and student learning. *Journal of Research in Science Teaching, 48*(2), 117-148.

Supovitz, J. A., & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(2), 963-980.

Weinbaum, E. H., & Supovitz, J. A. (2010). Planning ahead: Make program implementation more predictable. *Phi Delta Kappan, 91*(7), 68-71.

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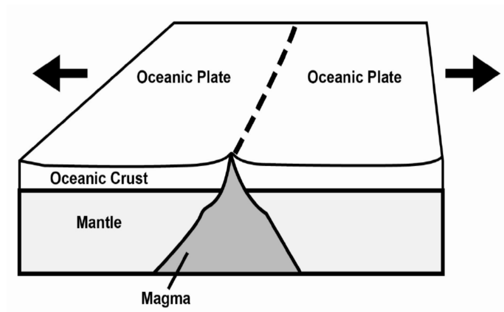
<table>
<tr>
<td>The major movement of the plates and description of plate boundaries of the Earth are...

A. Convergent
B. Divergent
C. Transform
D. All of the Above</td>
<td>The picture below shows a place on the ocean floor where two plates are moving apart. At this plate boundary (shown at the dotted line), rock material is rising to the surface.



A. Draw on the picture to show what is happening in the mantle that causes the plates to move apart.
B. What is happening in the mantle that helps to explain why the two plates are moving apart?
C. Put an X on the places in the picture above where the oldest rock can be found in the crust.
D. Explain your answer.</td>
</tr>
</table>

Figure 1.

Sample Earth Science Tasks: Typical (Left) and PBIS Study (Right)