Suggested Action

Begin the process of comparing your local curriculum to the endpoints for Earth and Space Sciences in the *Framework*. You may find that your curriculum or instructional materials have more topics and more detailed information or concepts than those outlined in the *Framework*. The opposite may be true for the third core idea, Earth and Human Activity, which describes how Earth's processes and human activity affect each other. Be aware of the progression of the endpoints in each grade band. The *Framework* has been very attentive to the progression of ideas for each of the core ideas. Local examples and illustrations of Earth science core ideas are excellent teaching resources. Begin to catalog them for use in the current curriculum or the revised curriculum, as it will help implement the *NGSS*.

Chapter 8

Dimension 3: Disciplinary Core Ideas: Engineering, Technology, and Applications of Science

Overview

The engineering, technology, and applications of sciences section has been organized under the following two core ideas and five component ideas.

Core Idea ETS1: Engineering Design

- ETS1.A: Defining and Delimiting an Engineering Problem
- ETS1.B: Developing Possible Solutions
- ETS1.C: Optimizing the Design Solution

Core Idea ETS2: Links Among Engineering, Technology, Science, and Society

- ETS2.A: Interdependence of Science, Engineering, and Technology
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World

Analysis

While the intent of this chapter is to help students learn how science is used through the engineering design process, the two core ideas have different goals. The goal of the first idea is to help students develop an understanding of engineering design, while the second is to help them make connections among engineering, technology, and science. Although the *language* defining the process of engineering design may be new to science educators, the *ideas* are not new for many of them, particularly those at the elementary level and those using project activities in their teaching. For example, students designing and building a structure in an elementary science unit have followed the three procedures described in the Core Idea ETS1, possibly without the explicit understanding of the engineering design process and use of the terminology.

The early paragraphs in this chapter provide the essential, but limited, direction that learning engineering requires, combining the engineering practices outlined in Chapter 3 with the understanding of engineering design contained in Chapter 8 in the same way that science involves both knowledge and a set of practices.

The second core idea is an excellent complement to the engineering core ideas taught in the science curriculum since it brings together the interdependence of engineering, technology, science, and society. Readers familiar with the standards for Science in Personal and Societal Perspectives in the *NSES* will see some overlap with the core ideas in this section of the *Framework*.

The core ideas in this chapter and those in Chapter 3 dealing with engineering practices may prove to be a significant shift for science educators when the *NGSS* appear. Although many teachers and instructional materials rely on activities that are engineering in nature, the language and specific outcome described in Core Ideas ETS1 and ETS2 are not normally included as part of the activities. A paradigm shift is called for that might be approached with the following professional development activities and curriculum development work.

Suggested Action

Form study or discussion groups to read and discuss the nature of engineering using resources such as the National Academy of Engineering publication *Standards for K–12 Engineering Education?* (NRC 2010b). This and many other reports can be downloaded for free at *www.nap.edu.*

Study the definitions in Box 8-1, "Definitions of Technology, Engineering, and Applications of Science" (p. 8-11), at the end of the chapter to help gain clarity on the distinction between engineering and technology. Notice the connection between the two definitions. An excellent book on the nature of technology is *The Nature of Technology: What It Is and How It Evolves* (Arthur 2009).

Assemble a team to begin assessing how and where engineering core ideas might be integrated in the science curriculum at each grade band in your school or district. Some courses or units lend themselves to this integration better than others. What are they? Do new activities or units need to be added? Can some of the existing activities be modified or supplemented to provide outcomes in engineering? Where and how can the endpoints from the practices of engineering and the core ideas in this chapter be combined as parallel outcomes of modified or new activities?

Identify or plan professional development activities to immerse teachers in doing engineering design projects and gaining knowledge of the language and endpoints expected of their students. Keep in mind that a thorough modification and revision of instructional material should wait until the new standards are reasonably complete and available.

PART III:
Realizing the Vision

Chapter 9
Integrating the Three Dimensions

Overview

This chapter describes the process of integrating the three dimensions (practices, crosscutting concepts, and core ideas) in the *NGSS* and provides two examples for its writers, as well as for the writers of instructional materials and assessments. The preceding chapters described the dimensions separately to provide a clear understanding of each; this chapter recognizes the need and value of integrating them in standards and instruction. The *Framework* is specific about this task as indicated by the following statement (p. 9-1): "A major task for developers will be to create standards that integrate the three dimensions. The committee suggests that this integration should occur in the standards statements themselves and in performance expectations that link to the standards."

This expectation is based on the assumption that "students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined. … At the same time, they cannot learn or show competence in practices except in the context of specific content" (p. 9-1).

Performance expectations are a necessary and essential component of the standard statements. These expectations describe how students will demonstrate an understanding and application of the core ideas. The chapter provides two illustrations in Table 9-1, "Sample Performance Expectations in the Life Sciences" (p. 9-12), and Table 9-2, "Sample Performance Expectations in the Physical Sciences" (p. 9-16), of what the performance expectation could look like for two core ideas.

Although it is not the function of the *Framework* or the *NGSS* to provide detailed descriptions of instruction, this *Framework* chapter offers a fairly extensive example—in narrative form—of what the integration of the three dimensions for a physical science core idea at each grade band (K–2, 3–5, 6–8, and 9–12) would look like. One of the unique features of this example is the inclusion of "boundary statements" that specify ideas that do *not* need to be included. The standard statements are expected to contain boundary statements.

Analysis

Although Tables 9-1 and 9-2 are extensive examples of performance expectation for two core ideas, they are not a model for the format of the standards statements that will appear in the *NGSS*. The practices and crosscutting concepts are only identified and not spelled out in performance language. We will not know the actual format and structure of the standards that integrate the three dimensions until the first draft is released, and we will not know specifics of the final standards until sometime later. The new integrated standards will be a significant departure from those in the previous national standards documents, and they will have a huge impact on instruction, instructional materials, and assessments for science educators.

There are few, if any, examples or precedents for this type of standard. Such standards may very well prescribe the instruction and assessment that should be included in the curriculum and instructional materials. Performance expectations indicate the core idea, the practice that should be used or at least emphasized, and the crosscutting concepts that should be included. The performance for each of the dimensions comes close to describing how each should be assessed. The detailed instructional strategies and instructional materials will be left to the instructor, but the outcomes suggested by the practices will be determined by the standard statements and the associated performance expectations.

Suggested Action

The development of instructional materials, their implementation, and the associated assessment from integrated standards will be the second major shift (after the inclusion of engineering) that appears in the *NGSS*. We recommend the following general strategies to accommodate this shift:

- Conduct extensive reading, form study groups, and explore other professional development avenues to become deeply familiar with the scientific and engineering practices, the crosscutting concepts, and the core ideas in the *Framework*. The integration of the dimensions will be most effective if educators have a thorough and clear understanding of each dimension.
- Study Tables 9-1 and 9-2 and the narrative example of instruction from the physical sciences.
- Begin searching for instructional materials that explicitly integrate the three dimensions. Examples may begin to appear in professional literature such as NSTA journals. Examine and evaluate them carefully.
- When the first draft of the *NGSS* appears, study carefully the content of a standard statement at your grade band. As a learning exercise, assemble a small team of colleagues and sketch out a series of lessons or a small unit to facilitate a group of students meeting the performance expectations in the standard. This exercise is only a sample of what will be required to meet the new performance expectations, but it will assist in your planning of longer-range activities and projects when the final version of the *NGSS* is published and adopted by your state or school district.

Chapter 10

Implementation: Curriculum Instruction, Teacher Development, and Assessment

Overview

Most readers will recall that the *NSES* include standards for the components of teaching, professional development, assessment, educational programs, and educational systems. This chapter acknowledges the value of those standards and the fact that the charge to the *Framework* developers did not include a similar comprehensive assignment to provide standards or even recommendations. This chapter assumes the task of analyzing the overall education system and discusses "what must be in place in order for [each component] to align with the framework's vision" (p. 10-1). In doing so, it depends heavily on a number of recent reports from the NRC that reviewed the research related to each component in the *Framework*. These include *Knowing What Students Know* (Pellegrino, Chudowsky, and Glaser 2001), *Investigating the Influence of Standards* (Weiss et al. 2002), *Systems for State Science Assessments* (Wilson and Bertenthal 2006), *America's Lab Report* (Singer, Hilton, and Schweingruber 2006), *Taking Science to School* (Duschl, Schweingruber, and Shouse 2007), and *Preparing Teachers* (NRC 2010a).

After briefly describing the total education system and calling for coherence within it, the *Framework* addresses the components of curriculum and instruction, teacher development, and assessment.

The section on curriculum and instruction lists a variety of "aspects for curriculum designers to consider that are not addressed in the framework … that the committee considers important but decided would be better treated at the level of curriculum design than at the level of framework and standards" (p. 10-5). These include the historical, cultural, and ethical aspects of science and its applications, and the history of scientific and engineering ideas and the individual practitioners.

Analysis

For many experienced science educators, this section of the *Framework* is the most important despite its limited treatment. The missing ingredient in the first release of the *NSES* and *Benchmarks* was the lack of extensive implementation at the state and local level. Both the *NSES* and the *Benchmarks* received a great deal of attention and some replication in state standards, but the standards for teaching, professional development, assessment, program, and systems did not receive equal emphasis. NSTA believes that for new standards to be implemented successfully, a significant emphasis must be placed on outreach and support for science educators.

The section in the *Framework* on instruction does not go into great depth on the topic and defers to the extensive discussion of the topic and the research behind it in *Taking Science to School* (Duschl, Schweingruber, and Shouse 2007). Teacher development and assessment sections are also light and depend on existing NRC reports previously listed in the overview section.

Suggested Action

The call to integrate the practices, crosscutting concepts, and the core ideas will require a new and greater emphasis on incorporating change in all components of the system. The *NGSS* are what is to be implemented, not the *Framework*, but the task of implementation needs to start now, long before the *NGSS* are published and adopted in states and school districts. It is not the role of this guide to spell out the multiple steps and decisions that need to be made to implement a new set of standards, but that process needs to begin now! The starting points have been outlined in the previous sections.

To stay informed, follow the NSTA *NGSS* website (*www.nsta.org/ngss*), which provides a continuous flow of information about the draft versions of *NGSS* as they are released.

Chapter 11
Equity and Diversity in Science and Engineering Education

Overview

This chapter highlights the issues in achieving equity in education opportunities for all students, summarizes the research on the lack of equity in education in general and science education in particular, describes what should be available for all students in broad strokes, and makes a limited number of specific recommendations to the standards developers. The discussion of inequity of education achievement among specific demographic groups is reduced to two key areas: (1) the differences in the opportunity to learn due to inequities in schools and communities; and (2) the lack of inclusiveness in instruction to motivate diverse student populations. The research is clear that all students, with rare exceptions, have the capacity to learn complex subject matter when support is available over an extended period of time.

The *Framework* recommends that the *NGSS* (1) specify that rigorous learning goals (standards) are appropriate for all students and (2) make explicit the need for the instructional time, facilities, and teacher knowledge that can help all students achieve these goals.

On a more general but no less significant level, the *Framework* recommendations address the need to equalize the opportunity to learn. This means providing inclusive science instruction, making diversity visible, and providing multiple modes of expression. To make science instruction more inclusive, the *Framework* suggests several strategies: approaching science learning as a cultural accomplishment, relating youth discourses to scientific discourses, building on prior interest and identity, and leveraging students' cultural funds of knowledge.

The final recommendation in the chapter focuses on creating assessments that use multiple opportunities for students to express their understanding of the content in multiple contexts and avoiding culturally biased assessment instruments.

Analysis

The *Framework* gives the critical issue of equity and diversity modest attention, but it provides a number of well-researched recommendations. Most of the recommendations in the chapter focus on instruction and cultural contexts of education more than the nature of standards. The limited attention to these issues in the *Framework*, due to the charge to the committee of writers, should in no way detract from its extreme importance.

Suggested Action

Schools should reexamine their progress with equity and diversity and reshape their efforts based on the specific recommendations provided in the *Framework*. There is no need to wait to address these issues until the *NGSS* are released; the issues of equity and diversity should be an ongoing agenda for all schools and teachers, and should be addressed aggressively and consistently.

Chapter 12
Guidance for Standards Developers

Overview

This chapter opens with the recommendation from *Systems for State Science Assessments* (Wilson and Bertenthal 2006) that standards should be "clear, detailed, and complete; reasonable in scope; rigorously and scientifically correct, and based on sound models of student learning … [and] should have a clear conceptual framework, describe performance expectations, and identify proficiency levels" (p. 12-1).

It then lists the following 13 specific recommendations for standard developers with a short discussion following each recommendation. (These recommendations are quoted directly from the *Framework*.)

1. Standards should set rigorous learning goals that represent a common expectation for all students (p. 12-2).
2. Standards should be scientifically accurate yet also clear, concise, and comprehensible to science educators (p. 12-2).
3. Standards should be limited in number (p. 12-3).
4. Standards should emphasize all three dimensions articulated in the framework—not only crosscutting concepts and disciplinary core ideas but also scientific and engineering practices (p. 12-3).
5. Standards should include performance expectations that integrate the scientific and engineering practices with the crosscutting concepts and disciplinary core ideas. These expectations should include criteria for identifying successful performance and require that students demonstrate an ability to use and apply knowledge (p. 12-4).
6. Standards should incorporate boundary statements. That is, for a given core idea at a given grade level, standards developers should include guidance not only about what needs to be taught but also about what does ***not*** need to be taught in order for students to achieve the standard (p. 12-4).
7. Standards should be organized as sequences that support students' learning over multiple grades. They should take into account how students' command of the practices, concepts, and core ideas becomes more sophisticated over time with appropriate instructional experiences (p. 12-5).
8. Whenever possible, the progressions in standards should be informed by existing research on learning and teaching. In cases in which insufficient research is available to inform a progression or in which there is a lack of consensus on the research findings, the progression should be developed on the basis of a reasoned argument about learning and teaching. The sequences described in the framework can be used as guidance (p. 12-5).
9. The committee recommends that the diverse needs of students and of states be met by developing grade band standards as an overarching common set for adoption by multiple

states. For those states that prefer or require grade-by-grade standards, a suggested elaboration on grade band standards could be provided as an example (p. 12-6).

10. If grade-by-grade standards are written based on the grade band descriptions provided in the framework, these standards should be designed to provide a coherent progression within each grade band (p. 12-7).
11. Any assumptions about the resources, time, and teacher expertise needed for students to achieve particular standards should be made explicit (p. 12-7).
12. The standards for the sciences and engineering should align coherently with those for other K–12 subjects. Alignment with the Common Core Standards in mathematics and English/language arts is especially important (p. 12-7).
13. In designing standards and performance expectations, issues related to diversity and equity need to be taken into account. In particular, performance expectations should provide students with multiple ways of demonstrating competence in science (p. 12-8).

Analysis

Although specifically addressed to Achieve Inc., the group writing the *NGSS*, the recommendations provide a preview of what to expect in the standards document. The reader will notice that the 13 recommendations are closely aligned with the content of the first 11 chapters.

Suggested Action

A few states and districts may be developing their own standards independent of the work being undertaken by Achieve Inc. To those few, the recommendations are germane and highly relevant. To the majority of readers, they are predictors of what to expect in the first and subsequent drafts of the *NGSS*. In most cases, more attention should be paid to the previous sections where the issues that give rise to the recommendations are well articulated.

Chapter 13

Looking Toward the Future: Research and Development to Inform K–12 Science Education Standards

Overview

Chapter 13 reminds the reader that the *Framework* is based on research and lays out the research agenda for the next near term (five to seven years) and the long term (seven years and beyond). The recommended agenda can be summarized with the following outline, which lists two major areas of research with a number of issues or questions under each.

I. Research to Inform Implementation and Future Revisions of the Framework
   - A. Learning and Instruction
     1. What are the typical preconceptions that students hold about the practices, crosscutting concepts, and core ideas at the outset?
     2. What is the expected progression of understanding, and what are the predictable points of difficulty that must be overcome?
     3. What instructional interventions (e.g., curriculum materials, teaching practices, simulations or other technology tools, instructional activities) can move students along a path from their initial understanding to the desired outcome?
     4. What general and discipline-specific norms and instructional practices best engage and support student learning?
     5. How can students of both genders and of all cultural backgrounds, languages, and abilities become engaged in the instructional activities needed to move toward more sophisticated understanding?
     6. How can the individual student's understanding and progress be monitored? (p. 13-2)
   - B. Learning Progressions
   - C. Scientific and Engineering Practices
   - D. Development of Curricular and Instructional Materials
   - E. Assessment
   - F. Supporting Teachers' Learning

II. Understanding the Impact of the Framework and Related Standards
   - A. Curriculum and Instructional Materials
   - B. Teacher and Administrator Development
   - C. Assessment and Accountability
   - D. Organizational Issues

Analysis

Throughout the *Framework*, the reader is reminded that the document is based on a considerable body of solid education research, which is cited frequently. It should be pointed out that the National Research Council does not do original research; it reviews and evaluates the research already completed by others. The NRC is a part of the National Academies, a private nonprofit institution that provides expert advice on some of the most pressing challenges facing the nation and the world through the publication of reports that have helped shape sound policies; inform public opinion; and advance the pursuit of science, engineering, and medicine. Several new documents are cited in this chapter, including *Learning and Instruction: A SERP (Strategic Education Research Partnership) Research Agenda* (Donovan and Pellegrino 2004), which influenced the agenda and research question on learning and instruction in the *Framework*. The questions in the report could lead to and shape local school district or university cooperative research activities.

Suggested Action

Motivated readers may want to acquire and study the various research reports from the NRC that have been cited in the earlier chapters. As the standards are released and adoption and implementation begin, the question of why many of the changes or shifts from the previous documents and recommendations for classroom practices were made will be asked. The background research can be useful in making local and state decisions for curriculum and assessment and defending them in public and legislative settings.

The suggested action items in the previous chapters provide a host of ideas for science educators and others to gain a deep understanding of the *Framework* as a stand-alone document and as a guide to the use of the forthcoming *NGSS*. We encourage you to pursue these and other opportunities with colleagues to better prepare for the new standards.

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NSTA believes the *Framework* provides valuable guidance and recommendations to encourage the development of standards that allow for the teaching of science in greater depth. We are a committed partner in the process of developing new standards and will stay involved to ensure that the voices of science educators are heard and that the *NGSS* are the best they can be.

NSTA is developing extensive resources to help science educators and other stakeholders address the changes that the *Framework* and the upcoming *Next Generation Science Standards* will bring. All resources will be available online at *www.nsta.org/ngss*. Also look for updates in NSTA's four member journals as well as in *NSTA Express* and *NSTA Reports*.

"Science, engineering, and technology permeate nearly every facet of modern life, and they also hold the key to meeting many of humanity's most pressing current and future challenges. Yet too few U.S. workers have strong backgrounds in these fields and many people lack even fundamental knowledge of them. This national trend has created a widespread call for a new approach to K–12 science education in the United States."

—*From the Executive Summary of* A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas

A Framework for K–12 Science Education provides a broad set of learning expectations for students as they study science and engineering throughout the K–12 years. The *Framework* guides the writers of the forthcoming *Next Generation Science Standards (NGSS)*; will influence curriculum, assessment, and teacher professional development decisions for years to come; and ultimately will help inspire new generations of science and engineering professionals and scientifically literate citizens.

This handy *Reader's Guide* unpacks the three key dimensions of the *Framework*—scientific and engineering practices, crosscutting concepts, and core ideas in each specific discipline—allowing teachers, administrators, curriculum developers, university professors, and others to more easily grasp how the soon-to-be-released *Next Generation Science Standards* will differ from the current standards. Harold Pratt, a former NSTA president, a career science coordinator, and a National Research Council senior program officer during the development of the *National Science Education Standards*, offers the following for each chapter of the *Framework*:

- An overview with a brief synopsis of key ideas
- An analysis of what is similar to and what is different from the *NSES*
- A suggested action to help readers understand and start preparing for the *NGSS*

This NSTA *Reader's Guide* is a critical companion to the *Framework* for science educators nationwide as they prepare to incorporate the upcoming standards into their teaching of science and engineering.

The *Reader's Guide* is also available as a free PDF from the National Science Teachers Association. Please visit *www.nsta.org/store* to download your copy. The print edition of *A Framework for K–12 Science Education* is expected in early 2012 from the National Academies and will be available for purchase through NSTA.

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