Title:	**Washington Science Standards**	
As Related To:	☐ Goal One: Advocacy for an effective, accountable governance structure for public education ☐ Goal Two: Policy leadership for closing the academic achievement gap. ☐ Goal Three: Policy leadership to increase Washington's student enrollment and success in secondary and postsecondary education	☒ Goal Four: Effective strategies to make Washington's students nationally and internationally competitive in math and science ☐ Goal Five: Advocacy for policies to develop the most highly effective K-12 teacher and leader workforce in the nation ☐ Other
Relevant To Board Roles:	☒ Policy Leadership ☐ System Oversight ☐ Advocacy	☐ Communication ☐ Convening and Facilitating
Policy Considerations / Key Questions:	What are the implications of the 2012 Fordham Report's assessment of Washington's science standards? What questions or issues should the Board track as the next wave of science standards (Next Generation Science Standards) is developed and implemented? What are the national trends in STEM education?	
Possible Board Action:	X Review ☐ Adopt ☐ Approve ☐ Other	
Materials Included in Packet:	X Memo ☐ Graphs / Graphics ☐ Third-Party Materials ☐ PowerPoint	
Synopsis:	The 2012 Fordham Report on The State of State Science Standards scored Washington's standards (and those of ten other states) with a grade of "C." Twelve states and the District of Columbia fared better, and 27 states fared worse. David Heil, who led the Board's review of Washington's science standards in 2008, will provide a perspective on the meaning of the Fordham Report's assessment. He will also preview the issues the Board may want to explore as Washington considers the next wave of science standards: Next Generation Science Standards. Washington is one of 26 lead states providing input and reactions to the work of the writers of the Next Generation Science Standards (NGSS). The NGSS are based on the *Framework of K-12 Science Education*, released in July 2011 by the National Research Council (NRC) of the National Academy of Sciences. The NGSS are scheduled to be released in fall 2012. Washington, as a lead state, has committed to giving "serious consideration" to adopting the new standards. The Heil presentation will focus on the overall, big picture implications of the Fordham Report and national trends in science and STEM education. It will be followed by a discussion led by Office of Superintendent of Public Instruction (OSPI) staff on some of the practical implications for consideration and implementation of new science standards.	

WASHINGTON SCIENCE STANDARDS: THE FORDHAM FOUNDATION REVIEW, PREPARING FOR NEXT GENERATION SCIENCE STANDARDS, AND NATIONAL TRENDS IN STEM EDUCATION

Background

One of the Board's five Strategic Plan goals is to promote effective strategies to make Washington's students nationally and internationally competitive in math and science.

The Board's work in the area of science since 2006 has included:

- Reviewing the state's science essential academic learning requirements and grade level expectations and recommending revisions to those standards (2007-2008).[1]
- Analyzing science course taking patterns as part of the Boards transcript study of 2008 graduates[2] (2008).
- Providing official comment and recommendations to the Superintendent of Public Instruction regarding the recommended science curricula (2009).
- Commissioning a review of science end-of-course assessments as exit exams (2008).
- Approving cut scores for the state science assessments (2011; August 2012).
- Approving 3 credits of science (not yet in rule) as part of the career and college ready graduation requirements.

Summary

The 2007 legislation that authorized SBE's review of science standards also directed the Board to be assisted in its work by an expert national consultant. The Board hired David Heil and Associates to work with a science advisory panel and lead the review. David Heil and Associates produced two reports; the first, a review of the standards[3] (May 2008) and the second, a review of the revised standards[4] (December 2008). The firm also prepared a white paper exploring the implications of using science end-of-course assessments for high school exit exams.[5]

David Heil's familiarity with Washington's science standards, adopted by the Superintendent of Public Instruction in 2009, and his knowledge of science standards and education nationally, make him well-qualified to help the Board put the findings of the 2012 Fordham Report, The State of State Science Standards, into perspective. In that report, Washington's science

[1] The 2007 Legislature directed the Board to review the science standards and recommend revisions to the superintendent of public instruction (SPI), and to provide official comment and recommendations to the SPI regarding the SPI's recommended science curricula.
[2] http://www.sbe.wa.gov/documents/SBE_Research_Brief_Science_FINAL01-04-10.pdf
[3] http://www.sbe.wa.gov/documents/ScienceStandardsReview050708.pdf
[4]http://www.sbe.wa.gov/documents/DHA%20Report2%20on%20Final%20WA%20Science%20Standards.pdf
[5] http://www.sbe.wa.gov/documents/EOC%20Briefing%20Paper2.pdf

standards earned a “C” grade, the same grade earned by Washington’s standards in 2005, when Fordham last reviewed them. However, Fordham’s criteria for evaluating states’ standards changed in the seven years between the two reports, so the rationale for the grades is not the same.

By comparison, the 2012 Fordham Report scored ten other states with a grade of “C”; twelve states and the District of Columbia fared better, and 27 states fared worse. See Attachment A for the foreword, introduction, and Washington section of the 2012 Fordham report.

In addition to helping the Board consider what meaning can be taken from Fordham’s evaluation of Washington’s standards, David Heil will address what lessons the Fordham Report may offer the state as Washington works toward the Next Generation Science Standards (NGSS), and what general questions or issues the Board should be tracking as this next wave of science standards is developed and implemented. He will also highlight national trends in Science, Technology, Engineering, and Mathematics (STEM) education.

Washington is one of 26 lead states providing input and reactions to the work of the writers of the NGSS. The NGSS are based on the *Framework of K-12 Science Education*, released in July 2011 by the National Research Council (NRC) of the National Academy of Sciences. Partners in the development of the NGSS include the National Research Council, National Science Teachers Association, American Association for the Advancement of Science, and Achieve. Sponsors include the Carnegie Corporation of New York, the Noyce Foundation, and DuPont. See Attachment B for an overview of the framework.

The NGSS are scheduled to be released in fall 2012. Washington, as a lead state, has committed to giving “serious consideration” to adopting the new standards. See Attachment C for details about the NGSS.

The Heil presentation will focus on the big-picture implications of the Fordham Report and national trends in science standards and STEM education. It will be followed by a discussion led by Office of Superintendent of Public Instruction (OSPI) staff on some of the practical implications for consideration and implementation of new standards.

The OSPI discussion will touch upon the following issues and questions:

- What is the state’s work as a lead state with NGSS, and what are the next steps in the upcoming 12-18 months?
- Washington has used different processes to adopt state standards, in part as a result of targeted legislative intervention.
    - How is the adoption of the Common Core State Standards similar to and different from the pending consideration of NGSS?
    - What would the optimal process be for making a decision about adopting NGSS and what role might SBE play?
- The NGSS are based on a three-dimensional framework that includes: 1) scientific and engineering practices; 2) crosscutting concepts; and 3) disciplinary core ideas. What are the practical implications for:
    - teachers to implement standards that would integrate these three dimensions?
    - student learning (and ultimately, achievement)?
- Currently, Washington requires a high school biology end-of-course (EOC) assessment for graduation. What are the assessment implications that might arise if the state adopts new standards?

- The Board has approved 3 credits of science for all students to graduate, although the rule has not yet been adopted. The current requirement is 2 credits. Will the scope of the NGSS require more than 2 credits of science?

Action Taken

The presentation is for Board discussion only; no action will be taken.

Attachment A

The State of State Science Standards

2012

State reviews by Lawrence S. Lerner, Ursula Goodenough, John Lynch, Martha Schwartz, and Richard Schwartz
NAEP review by Paul R. Gross

FOREWORD BY CHESTER E. FINN, JR., AND KATHLEEN PORTER-MAGEE

THOMAS B. FORDHAM INSTITUTE
ADVANCING EDUCATIONAL EXCELLENCE

Contents

Foreword

By Chester E. Finn, Jr., and Kathleen Porter-Magee

Since *Sputnik* shot into orbit in 1957, Americans have considered science education to be vital to our national security and economic competitiveness. The impact of the Soviet satellite launch on American science classrooms was almost immediate. Shirley Malcolm, a leader in the field of science education (and presently head of education programs for the American Association for the Advancement of Science), was a young student in Alabama at the time. She described the swift and palpable shift in the way science was taught:

> **We stopped having throwaway science and started having real science...All of a sudden everybody was talking about it, and science was above the fold in the newspaper, and my teachers went to institutes and really got us all engaged. It was just a time of incredible intensity and attention to science.[1]**

The impact on public opinion was just as profound—and national concern over the quality of American science, and science education, has continued for the past half century. According to a 2011 survey, 74 percent of Americans think STEM (Science, Technology, Engineering, and Math) education is "very important." Only two percent say it's "not too important."[2]

Yet this strong conviction has not translated into strong science achievement. The 2009 National Assessment of Educational Progress (NAEP) found barely one-third of fourth graders in the United States at or above the "proficient" level in science, with those proportions slipping to 30 percent in eighth grade and a woeful 21 percent in twelfth grade.[3] Another recent study reported that just 30 percent of our high school graduates are prepared for college-level work in science.[4]

International comparison is even more disheartening. The most recent PISA assessment, released in December 2010, showed fifteen-year-olds in the United States ranking a mediocre twenty-third out of sixty-five countries. By contrast, youngsters in Shanghai ranked first, demonstrating both China's commitment to science education—and the various bounties that accompany it—and that nation's capacity to deliver on its educational aspirations.

Similarly, on the 2007 TIMSS science assessment, American eighth graders overall ranked eleventh out of forty-eight nations and were trounced not only by the likes of Singapore and Japan, but also by the Czech Republic, Hungary, and Slovenia.[5] Even more distressing, only 10 percent of American

---

[1] Cornelia Dean, "When Science Suddenly Mattered, in Space and in Class," *New York Times*, September 25, 2007, http://www.nytimes.com/2007/09/25/science/space/25educ.html?pagewanted=all.

[2] Research!America, *Your Congress-Your Health: National Public Opinion Poll* (Alexandria, VA: Research!America, March 2011), http://www.yourcongressyourhealth.org/admin/Editor/assets/yourcongress2011.pdf.

[3] Institute of Education Sciences, *Science 2009: National Assessment of Educational Progress at Grades 4, 8, and 12* (Washington, D.C.: National Center for Education Statistics, January 2011), http://nces.ed.gov/nationsreportcard/pdf/main2009/2011451.pdf.

[4] ACT, Inc., *The Condition of College & Career Readiness* (Iowa City, IA: ACT, Inc., 2011), http://www.act.org/research/policymakers/cccr11/readiness1.html.

[5] Patrick Gonzalez, *Highlights from TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context* (Washington, D.C.: National Center for Education Statistics, September 2009), http://nces.ed.gov/pubs2009/2009001.pdf.

eighth graders scored at or above the TIMSS "advanced" level. By contrast, 32 percent of students in Singapore reached that level.

The evidence is indisputable—and should be alarming. While no one test can communicate the full picture of education achievement, if our students' performance on international assessments like TIMSS and PISA is any indication, the United States is doing little more than *talking* about the importance of getting science education right.

Why is this? How can it be that, for more than five decades, Americans have voiced so much concern about science education yet made so little progress in delivering it? There are, of course, multiple explanations, starting with the blunt fact that few states and communities have taken concrete action to build world-class science programs into their primary and secondary schools. Without such programs in place to deliver the goods, our Sputnik-induced anxieties remain fully justified some fifty-five years later.

A solid science education program begins by clearly establishing what well-educated youngsters need to learn about this multi-faceted domain of human knowledge. Here, the first crucial step is setting clear academic standards for the schools—standards that not only articulate the critical science content students need to learn, but that also properly sequence and prioritize that content. In the light of such standards, teachers at each grade level can clearly see where they should focus their time and attention to ensure that their pupils are on track toward college- and career-readiness. That doesn't mean it will happen, of course. As we at the Thomas B. Fordham Institute have repeatedly noted, standards alone cannot drive outstanding achievement. But they are a necessary starting point. They are the score for conductors, musicians, instrument makers, and more. They are the foundation upon which rigorous curricula and instructional materials and assessments are built. They are the template for preparing science teachers for our classrooms.

Fordham has a long-standing interest in science standards and a history of reviewing them with care and rigor. We published our first analysis of state science standards in 1998 and a follow-up review in 2005. Unfortunately, the findings from both evaluations were not good. In 1998, just thirty-six states had even set standards for science, and only thirteen of those earned grades from our reviewers in the A or B range. By 2005, though every state except Iowa had articulated K-12 science standards, the results were equally disheartening: just nineteen earned honors grades, and the overall average was barely a C.

Why So Different?

This variability in the quality of standards is as unacceptable as it is unnecessary. As one of us observed in our 1998 review:

> **If any subject has the same essentials everywhere, after all, it's science. I can think of no sound reason why what is expected of teachers and children in biology or chemistry should be different in Tennessee...than Indiana. Indeed, it should be approximately the same as what is expected in Singapore and Germany, too.[6]**

Science is not, of course, the only core subject where it makes no sense for young Americans to be held to different standards depending on where they live. That is why the Council of Chief State Schools Officers (CCSSO) and National Governors Association (NGA) came together in 2009 to build rigorous common standards for English language arts (ELA) and mathematics. These common standards aimed to articulate the knowledge and skills that all students need to master across grades K-12 if they are to succeed in college and career. The result of this effort was the 2010 "Common Core" standards for ELA and math. Notably, these standards are clearer and more rigorous than those in use in most states. Fordham's own analysis, comparing state ELA and math standards with the Common Core standards, concluded that, "out of 102 comparisons—fifty-one jurisdictions times two subjects—we found the Common Core clearly superior seventy-six times."[7]

Today, a similar push toward quality common standards is underway for science. Twenty-six states have teamed up with Achieve, Inc. to craft "Next Generation Science Standards" (NGSS). This group intends to do for science what the CCSSO and NGA did for ELA and math: create a set of clear, rigorous, and specific expectations that states will have the option to adopt as their own. Indeed, such a movement is long overdue.

Like the drafters of the Common Core standards, Achieve and its partners will look to national and international models as starting points for the development of the NGSS. Among those models is the *Framework for K-12 Science Education* released by the National Research Council (NRC) in July 2011. While not a set of standards, the NRC states that the *Framework* includes "the key scientific practices,

[6] Chester E. Finn, Jr., foreword to *State Science Standards 1998*, by Lawrence S. Lerner (Washington, D.C.: Thomas B. Fordham Institute, March 1998), http://www.edexcellence.net/publications/stsciencestnds.html.

[7] Sheila Byrd Carmichael, Gabrielle Martino, Kathleen Porter-Magee, and W. Stephen Wilson, *The State of State Standards--and the Common Core—in 2010* (Washington, D.C.: Thomas B. Fordham Institute, July 2010), http://www.edexcellence.net/publications/the-state-of-state.html.

concepts, and ideas that all students should learn by the time they complete high school" and that it is "intended as a guide for those who develop science education standards, those who design curricula and assessments, and others who work in K-12 science education."[8]

In August 2011, we asked the distinguished biologist (and veteran Fordham science reviewer) Paul R. Gross to evaluate the NRC *Framework*. Overall, he gave it a solid B-plus, and found that the document includes nearly all of content necessary for a rigorous K-12 science curriculum.[9] Dr. Gross did caution, however, that the *Framework* may have paid too much attention to engineering and technology, as well as to "science process" skills. And he warned that standards writers using this framework as a model will need to make difficult decisions about priorities that were not made by the *Framework* authors.

When those "common" standards for science are ready, we at the Thomas B. Fordham Institute will review and evaluate them. But we also want to help states now—for today's students can't wait for common science standards, and today's states are using academic standards of their own as the basis for what their schools will teach and their children will learn.

Hence it's time for a fresh review of existing state science standards. While forty-nine states and the District of Columbia had articulated science standards when we examined them in 2005, Iowa subsequently wrote its own standards and forty-two states and the District of Columbia have changed their standards during the ensuing years.

Our Approach

This report is part of a comprehensive series of fresh appraisals by Fordham of state, national, and international standards in all core content areas. Here we provide analyses of the K-12 science standards currently in place in all fifty states and the District of Columbia, as well as the assessment framework that undergirds the NAEP science assessment. These reviews should also help states gauge the comparative strengths and weaknesses of their standards vis-à-vis the forthcoming Next Generation Science Standards—and how they stack up today against the science education expectations that undergird NAEP.

> **Why Review NAEP?**
>
> The National Assessment of Education Progress (NAEP) is the most-often used barometer of student learning in science. Results from NAEP are used to compare student achievement across states and to judge states' student-proficiency levels. Because NAEP is so central to the conversation on state and national science achievement, we felt it was important to analyze the quality of its implicit standards—embodied in its assessment framework—to see how they compare with the quality of each state's standards.

For these reviews, we have enlisted the help of several veteran reviewers, all of them experts in their field. Lawrence Lerner joined us as lead author for this evaluation of state science standards. Dr. Lerner has played a role in all of our science reviews, dating back to 1998. This time he is joined by a team of experts: Ursula Goodenough, who evaluated life science; Richard Schwartz, who primarily reviewed chemistry and physical science; Martha Schwartz, who analyzed earth and space science; and John Lynch, who evaluated "science inquiry" standards.

In addition, Dr. Gross rejoined us to appraise the NAEP assessment framework for science.

Our experts employed new and improved content-specific criteria as well as the "common grading metric" that has been used for all of the reports in this cycle of Fordham standards reviews.[10] Application of those criteria and the common metric yields—for every state in every subject—a two-part score: a tally from zero to seven for "content and rigor," and a tally from zero to three for "clarity and specificity." These were combined such that each set of standards obtained a total number grade (up to ten), which was then converted to a letter grade (from A through F). (For more detail, see Appendix A: Methods, Criteria, and Grading Metric.)

What We Found

The results of this rigorous analysis paint a fresh—but still bleak—picture. A majority of the states' standards remain mediocre to awful. In fact, the average grade across *all* states is—once again—a thoroughly undistinguished C. (In fact, it's

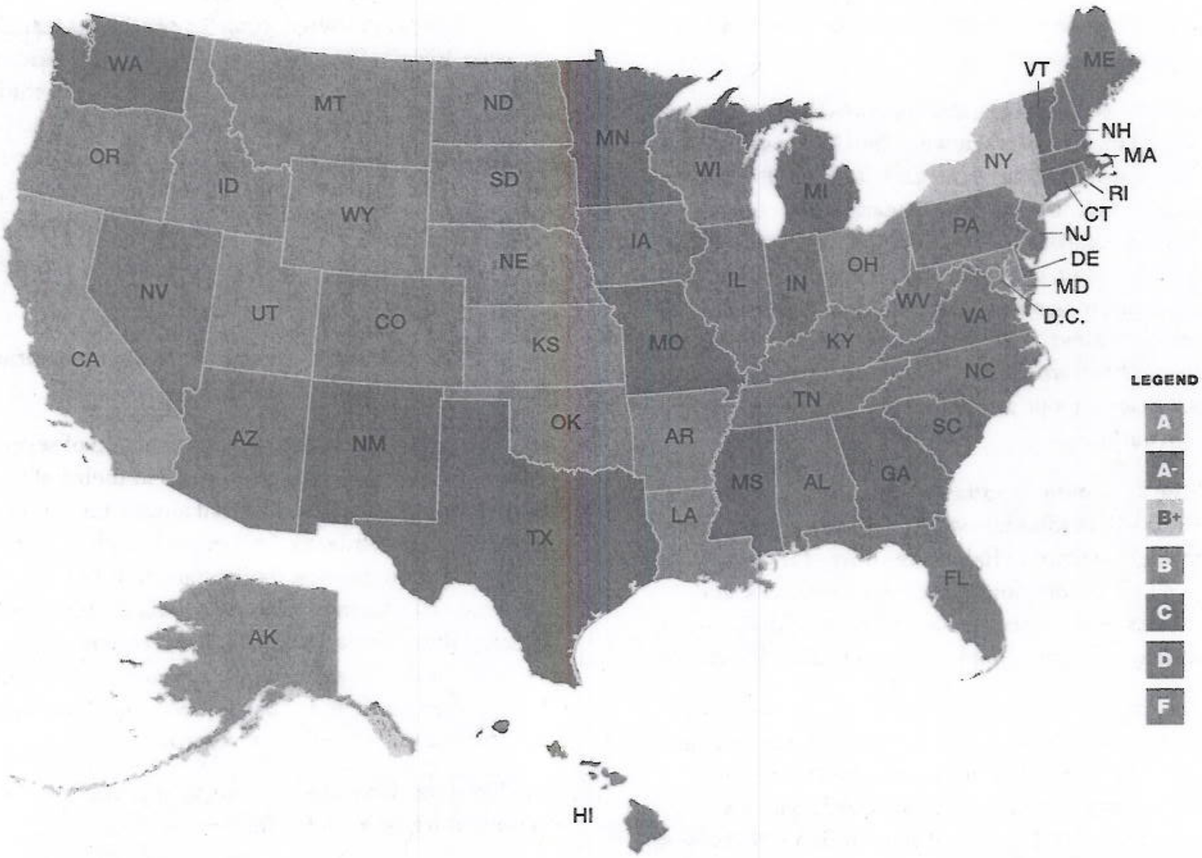
---

[8] National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (Washington, D.C.: National Research Council, July 2011), http://www.nap.edu/catalog.php?record_id=13165.

[9] Paul R. Gross, *Review of the National Research Council's Framework for K-12 Science Education* (Washington, D.C.: Thomas B. Fordham Institute, October 2011), http://www.edexcellence.net/publications/review-of-the-nrc-framework-for-k12-science-education.html.

[10] To read our 2010 review of state ELA and math standards and the Common Core, see http://www.edexcellence.net/publications/the-state-of-state.html. For our 2011 analysis of state U.S. History standards, see http://www.edexcellence.net/publications/the-state-of-state-us.html.

State Science Standards Grades, 2012



a low C.) In twenty-seven jurisdictions, the science standards earn a D or below. Yet this very weakness in what states expect of their schools, teachers, and students in science suggests that a purposeful focus on improving—or replacing—today's standards could be a key part of a comprehensive effort to boost science performance.

Two jurisdictions—California and the District of Columbia—have standards strong enough to earn straight As from our reviewers. Four other states—Indiana, Massachusetts, South Carolina, and Virginia—earn A-minuses, as does the NAEP assessment framework. And seven states earn grades in the B range. But this also means that just thirteen jurisdictions—barely 25 percent, and fewer than in 2005—earn a B or better for setting appropriately clear, rigorous, and specific standards.

Of course, as Dr. Lerner noted in 1998:

> **When it comes to academic standards...even a "B" ought not be deemed satisfactory. In a properly organized education system, standards drive everything else. If they are only "pretty good," then "pretty good" is the best the system is apt to produce by way of student learning. No state should be satisfied with such a result. Hence, no state should be satisfied with less than world-class standards in a core academic subject such as science.**

States looking to improve their standards, however, need not start from scratch, or even wait for the NGSS. They can look to places like California and the District of Columbia, and also to the NAEP assessment framework, for models of excellence.

Let us repeat that even the finest of standards alone will never yield outstanding academic achievement. Several states with exemplary science standards still aren't serious about setting high proficiency bars on their assessments. Others don't hold students (or their teachers) properly accountable for learning (or successfully imparting) important content. And still others haven't provided (or directed teachers to) the curricular and instructional resources that teachers need to drive achievement. But,

Table 1. 2005 and 2012 Grades in Alphabetical Order

Jurisdiction	2005 Grade	2012 Grade
Alabama	F	D
Alaska	F	F
Arizona	B	D
Arkansas	D	B
California	A	A
Colorado	B	D
Connecticut	C	C
Delaware	C	C
District of Columbia	C	A
Florida	F	D
Georgia	B	C
Hawaii	F	D
Idaho	F	F
Illinois	B	D
Indiana	A	A-
Iowa	N/A	D
Kansas	F	B
Kentucky	D	D
Louisiana	B	B
Maine	D	D
Maryland	B	B
Massachusetts	A	A-
Michigan	D	C
Minnesota	B	C
Mississippi	F	C
Missouri	C	C
Montana	F	F
Nebraska	F	F
Nevada	D	D
New Hampshire	F	D
New Jersey	B	D
New Mexico	A	C
New York	A	B+
North Carolina	B	D
North Dakota	D	F
Ohio	B	B
Oklahoma	F	F
Oregon	F	F
Pennsylvania	C	D
Rhode Island	C	D
South Carolina	A	A-
South Dakota	D	F
Tennessee	B	D
Texas	F	C
Utah	C	B
Vermont	C	C
Virginia	A	A-
Washington	C	C
West Virginia	B	D
Wisconsin	F	F
Wyoming	F	F

while standards alone won't drive achievement, they are an important place to start.

Changes since 2005

Of the forty-four jurisdictions that have revised or replaced their science standards since our 2005 analysis, eleven have shown some improvement, and some of that improvement has been dramatic (see Table 1). Kansas, for example, moved from an F to a B and Arkansas moved from a D to a B. The District of Columbia rose from a mediocre C in our last analysis to a best-in-class A this time.

By contrast, sixteen states managed to make their standards *worse* since 2005. In fact, five of them—Colorado, New Jersey, North Carolina, Tennessee, and West Virginia—dropped from Bs to Ds.

On balance, the combination of improvements and worsenings had little impact on our national average. In both 2005 and 2012, the average grade for state science standards was a minimal C.[11]

[11] Note, however, that our criteria have changed since 2005. Therefore, changes in a state's grade could be due to changes in the quality of the standards, changes in our criteria, or both. For more information on our grading metric, see Appendix A.

anti-evolution bills were introduced in six state legislatures. (Thankfully, none made it into law.) And two similar bills were pre-filed in New Hampshire for the 2012 legislative session,[15] as well as one in Indiana.[16]

Of course, most anti-evolution efforts are aimed more directly at the standards themselves. And these tactics are far more subtle than they once were. Missouri, for example, has asterisked all "controversial" evolution content in the standards and relegated it to a voluntary curriculum that will not be assessed. (Sadly, this marks a step back from that state's coverage of evolution in 2005.) Tennessee includes evolution only in an elective high school course (not the basic high school biology course). And Maryland includes evolution content in its standards but explicitly excludes crucial points from its state assessment.

Other states have undermined the teaching of evolution by singling it out as somehow not quite as "scientific" as other concepts of similar breadth. A common technique—used to a greater or lesser extent by Colorado, Missouri, Montana, and West Virginia—is to direct students to study its "strengths and weaknesses."

Far too often, important evolution content is included, but minimally. Some states mention evolution just once in their standards and never revisit it. Others—including Indiana, Iowa, Kansas, Kentucky, Michigan, and Nebraska—unnecessarily delay it until high school.

Even some of the nation's best standards subtly undermine the teaching of evolution. In California, for example, students are told to "understand science, not necessarily [to] accept everything taught." In New York, students learn that "according to many scientists, biological evolution occurs through natural selection." (This is not according to "many" but, in fact, *all* true scientists.)

Finally, conspicuously missing from the vast majority of states' standards is mention of *human* evolution—implying that elements of biological evolution don't pertain to human life. This marks a subtle but important victory for creationists: Even states with thorough and appropriate coverage of evolution (e.g., Massachusetts, Utah, and Washington) shy away from linking the controversial term with ourselves. Only four states—Florida, New Hampshire, Iowa, and Rhode Island—openly embrace human evolution in their current science standards. (Pennsylvania, which referenced human evolution in its previous standards, has omitted it from the more recent version.)

Problem 2: A Propensity to be Vague

Educators should not be confronted with standards that are so vague as to be meaningless—and yet, based on our current analysis, that is precisely what many states have imposed on their teachers. In fact, only seven states had standards clear enough to earn them full-credit scores of three out of three points for clarity and specificity. Twenty-nine earned a one or zero out of three.

A middle school teacher in New Hampshire, for example, will come face to face with the following: "Identify energy as a property of many substances." Pennsylvania offers the equally baffling "Explain the chemistry of metabolism." Such empty statements can do little to inform curriculum development or instruction, and give no guidance to assessment developers.

Similarly, New Jersey students are asked to:

> **Demonstrate understanding of the interrelationships among fundamental concepts in the physical, life, and Earth systems sciences. (grade 4)**
>
> **Use outcomes of investigations to build and refine questions, models, and explanations. (grade 4)**

These expectations contain virtually no specific content; it's impossible to determine what students should actually know or be able to do. To our dismay, similarly vague and meaningless statements are common across far too many state standards.

---

[15] House Bill 1148, introduced by Jerry Bergevin (R-District 17), would charge the state board of education to "[r]equire evolution to be taught in the public schools of this state as a theory, including the theorists' political and ideological viewpoints and their position on the concept of atheism." House Bill 1457, introduced by Gary Hopper (R-District 7) and John Burt (R-District 7), would charge the state board of education to "[r]equire science teachers to instruct pupils that proper scientific inquire [*sic*] results from not committing to any one theory or hypothesis, no matter how firmly it appears to be established, and that scientific and technological innovations based on new evidence can challenge accepted scientific theories or modes." Although HB 1457, as drafted, is silent about intelligent design, Hopper's initial request was to have a bill drafted that would require "instruction in intelligent design in the public schools." Both bills were referred to the House Education Committee; HB 1148 is scheduled for hearing on February 9, 2012, and HB 1457 is scheduled for hearing on February 14, 2012.

[16] Senate Bill 89, pre-filed in the Indiana Senate and referred to the Committee on Education and Career Development, would, if enacted, amend the Indiana Code to provide that "[t]he governing body of a school corporation may require the teaching of various theories concerning the origin of life, including creation science, within the school corporation." The sponsor of the bill is Dennis Kruse (R-District 14), who chairs the Senate Committee on Education and Career Development.

A few, however, have crafted clear and specific standards that could easily form the basis of a rigorous K-12 science curriculum. For instance, the California standards explain:

> **Electricity and magnetism are related effects that have many useful applications in everyday life. As a basis for understanding this concept:**
>
> - ***Students know*** **how to design and build simple series and parallel circuits by using components such as wires, batteries, and bulbs.**
> - ***Students know*** **how to build a simple compass and use it to detect magnetic effects, including Earth's magnetic field.**
> - ***Students know*** **electric currents produce magnetic fields and know how to build a simple electromagnet.**
> - ***Students know*** **the role of electromagnets in the construction of electric motors, electric generators, and simple devices, such as doorbells and earphones.**
> - ***Students know*** **electrically charged objects attract or repel each other.**
> - ***Students know*** **that magnets have two poles (north and south) and that like poles repel each other while unlike poles attract each other.**
> - ***Students know*** **electrical energy can be converted to heat, light, and motion. (grade 4)**

This standard leaves no question as to what, precisely, students should know or be able to do.

Alas, such cogent and unambiguous writing is distressingly rare.

Problem 3: Poor Integration of Scientific Inquiry

For at least the past fifteen years—possibly even longer—science educators, curriculum developers, and standards writers have focused greater and greater attention on "inquiry-based learning." In practice, this means helping students learn scientific content through discovery, as opposed to through direct instruction of specific content. Indeed, the National Science Teachers Association (NSTA) recommends that all K-16 teachers "embrace scientific inquiry" and that they "make it the centerpiece of the science classroom."[17]

Of course, inquiry has an important role in science classrooms. Students should learn important process and methodology skills. They should be introduced to important concepts like theory and hypothesis early in their K-12 education, and they should learn about the history and evolution of science.

Unfortunately, in too many states, the inquiry standards are vague to the point of uselessness. In Idaho, for instance, students are merely asked to "make observations" or to "use cooperation and interaction skills." And Iowa schoolchildren are directed to:

> **Make appropriate personal/lifestyle/technology choices, evaluate, observe, discuss/debate, recognize interactions and interdependencies at all levels, explain, describe environmental effects of public policy, choose appropriate course(s) of action.**

Such statements are devoid of any teachable content and leave teachers with no guidance as to how they can incorporate genuine scientific inquiry skills into their instruction.

Furthermore, inquiry standards can only enhance student learning if they are meaningfully linked to content. Unfortunately, too many states treat inquiry as an afterthought or add-on. In Michigan, for example, a stand-alone inquiry standard asks first graders to "make careful and purposeful observations in order to raise questions, investigate, and make meaning of their findings." Such expectations—which are distressingly common—present lofty goals that are hollow when not integrated with content.

Another common problem with state inquiry standards is their failure to address the history of science properly. Far too often, the history of science is missing entirely. And of the states that do include it, too many include overly broad directives that lack any real substance. In Maryland, for instance, students are told only that science has been done by "different kinds of people, in different cultures, at different times," an inane statement that gives teachers no direction as to what important scientific history students should learn.

Problem 4: Where Did All the Numbers Go?

Mathematics is integral to science. Yet few states make the link between math and science clear—and many seem to go to great lengths to avoid mathematical formulae and equations altogether. The result is usually a clumsy mishmash of poor writing that could much more easily and clearly be expressed in numbers.

It makes sense, of course, to focus science education on qualitative matters in the earlier grades, since students have not yet acquired a broad mathematical background and there is still plenty of qualitative material they need to learn. For the fourth-grade student, it is fine to define

---

[17] National Science Teachers Association, "NSTA Position Statement: Scientific Inquiry," October 2004, http://www.nsta.org/about/positions/inquiry.aspx?print=true.

energy as "what makes things happen," as many states do in one way or another. But once students have learned some algebra—it doesn't need to be a lot—it is important to make things quantitative, as in this standard from the District of Columbia:

> **Recognize that when a net force, F, acts through a distance, Δx, on an object of mass, m, which is initially at rest, work, $W = F\Delta x$, is done on the object; the object acquires a velocity, v, and a kinetic energy, $K = \frac{1}{2} mv^2 = W = F\Delta x$. (high school physics)**

Only then can the student understand such vital principles as the law of conservation of energy, because that understanding depends on comparing two numbers and showing that they are the same.

Unfortunately, few states take the approach of progressing from qualitative to quantitative insights. Far more typical is this passage from Illinois:

> **Understand that energy, defined somewhat circularly, is 'the ability to change matter,' or 'the ability to do work.' Understand that energy is defined by the way it is measured or quantified. Understand the difference between potential and kinetic energy. (grade 11)**

Such a limited definition of energy cannot possibly prepare students for college-level work.

While physics is the most mathematical of the sciences, a genuine understanding of chemistry also depends on the ability to perform quantitative operations. Such vital concepts as equilibrium, ion concentration, and many others are entirely dependent upon that ability. Nor can one acquire a keen insight into the other high school sciences without some exposure to quantitative methods.

• • •

Every state has the resources to produce excellent K-12 science standards. It is our hope that a closer approach to this ideal appears in the not-too-distant future, as states independently pen much improved standards, adopt (or crib from) existing excellent ones, or embrace more or less nationwide models that have been prepared and scrutinized by recognized experts.

SCIENCE

Washington

GRADE	SCORES		TOTAL SCORE
C	Content and Rigor	3/7	6/10
	Clarity and Specificity	3/3	

REPORT CARD

Content & Rigor	**3.3**
Scientific Inquiry & Methodology	5
Physical Science	3
Physics	0
Chemistry	0
Earth & Space Science	5
Life Science	7
Clarity & Specificity	**2.9**

Average numerical evaluations

Document(s) Reviewed

▶ *Washington State K-12 Science Learning Standards*. 2009. Accessed from: http://www.k12.wa.us/Science/Standards.aspx

Overview

Washington's science standards are a study in extremes. In some areas—notably life science—the content is clearly presented, thorough, and free from errors. By contrast, other disciplines suffer from glaring omissions of important content. Taken together, Washington's standards earn an average grade, but this average masks wild variability in quality.

Organization of the Standards

The Washington science standards are divided first into four "Essential Academic Learning Responsibilities" (EALRs): systems, inquiry, application, and the domains of science. Only the last of these is devoted to science content, and it is divided into three domains: life science, physical science, and earth and space science.

Each EALR is then divided into a series of "big ideas." (There are nine big ideas in the domains of science EALR.) Then the state provides a core content summary that broadly describes what students should know and be able to do within each big idea.

Finally, the state provides content standards and performance expectations for each of five grade bands: K-1, 2-3, 4-5, 6-8, and 9-12. The content standards describe what students should know, and the performance expectation describes what they should be able to do. For instance, one content standard and related performance expectation for grades K-1 explains:

	Content Standard	**Performance Expectation**
	Students know that:	***Students are expected to:***
K-1 ES2A	**Some objects occur in nature; others have been designed and processed by people.**	**Sort objects into two groups: *natural* and *human-made*.**

Content and Rigor

The Washington standards hit glorious peaks—see life science in particular—and equally deep valleys.

High school physics and chemistry are essentially absent, but earth and space science offers some redemption.

Scientific Inquiry and Methodology

The Washington process standards cover most of the content that students need to learn, though they do so in a way that's neither particularly inspired nor particularly offensive. Fourth- and fifth-grade students, for example, are told that:

> **Scientists plan and conduct different kinds of *investigations*, depending on the *questions* they are trying to answer. Types of *investigations* include systematic *observations* and descriptions, *field studies*, *models*, and *open-ended explorations* as well as *controlled experiments*. (grades 4-5)**

Given a pre-selected research question, the related performance expectation asks students to:

> **...plan an appropriate *investigation*, which may include systematic *observations*, *field studies*, *models*, *open-ended explorations*, or *controlled experiments*.**
>
> **Work collaboratively with other students to carry out a *controlled experiment*, selecting appropriate *tools* and demonstrating safe and careful use of equipment. (grades 4-5)**

Like most of the inquiry standards, these are generally clear and grade-appropriate, and the content progresses well through the grades.

The standards do have a few flaws, however. As in many other states, some expectations descend into platitudes. For instance, the claim that people "in all cultures have made and continue to make contributions to society through science and technology" is overly broad—and is not entirely true. And the history of science receives no mention.

Physical Science/High School Physics/High School Chemistry

In general, the physical science standards are succinctly and correctly stated, in proper logical order. For instance, in the grade band covering second and third grades we find:

> ***Motion* can be *described* as a change in position over a period of time.**
>
> **There is always a *force* involved when something starts moving or changes its *speed* or direction of *motion*.**
>
> **A greater *force* can make an object move faster and farther.**
>
> **The relative strength of two *forces* can be *compared* by observing the difference in how they move a *common* object. (grades 2-3)**

Now that is good physics—and quite a lot of it—insightfully stated so that a second or third grader can understand it. Similarly challenging but reasonable expectations of students continue in higher grades.

Quantitative treatments of mechanics and other subfields of physics begin modestly in sixth through eighth grades, and in high school, mathematical statements are used wherever necessary.

The high school physical science material is excellent at a relatively low level, with first-rate information for planning a ninth-grade course. Unfortunately, there are no higher-level standards that could inform a rigorous high school physics course. And even for a physical science course, much essential material is missing. For instance, thermodynamics is slighted, as is optics.

Chemistry is covered only within the context of physical science, as there is no separate course devoted to high school chemistry. No doubt because it isn't treated separately, there are huge blind spots. For example, ionic and covalent bonds are mentioned—but no others. Nothing about molarity appears, nor any discussion of the prediction of chemical reactions between elements. The list of omissions goes on and on.

Earth and Space Science

Some subjects in this category are covered quite well, especially those related to space. For example, stars and galaxies, motion of planets, the Milky Way, and the solar system are all well covered. Standards addressing earth layers are equally strong, as demonstrated by the following standard:

> **The solid Earth is composed of a relatively thin crust, a dense metallic core, and a layer called the mantle between the crust and core that is very hot and partially melted. (grades 6-8)**

By contrast, other topics, many dealing with solid-earth processes, are incomplete or ignored. For example, there is scant mention of minerals (except when they are dissolved) and the mechanics of earthquakes and volcanoes. While plate tectonics gets some mention—especially in the elementary grades—the evidence supporting the theory is missing. There are also several gross errors or oversimplifications in the standards. Take, for example, the following performance expectation:

> ***Explain how* the age of landforms can be estimated by studying the number and thickness of rock layers, as well as *fossils* found within rock layers. (grades 6-8)**

For starters, the standard should ask students to explain the age of rocks, not of landforms. Furthermore, the phrase "the number and thickness of rock layers" is so oversimplified, it's simply wrong.

Similarly, the following standard oversimplifies the process of weathering:

> ***Weathering* is the breaking down of rock into pebbles and sand caused by physical processes such as heating, cooling, and pressure, and chemical processes such as acid rain. (grades 4-5)**

In fact, it's not the heating and cooling of rocks that is the major cause of physical weathering but rather the presence of *water* during such temperature shifts, an important distinction worth mentioning. And the products of weathering consist of more than just pebbles and sand; they also include clay and dissolved minerals.

There are some brighter spots. Fossils are thoroughly covered, and much time is spent explaining stars, galaxies, and planets and their motion. The notion of deep time is squarely addressed. Washington even produces some "wow" moments; its version of the ubiquitous "constructive and destructive forces" idea is more useful than most, as it specifically addresses uplift, weathering, and erosion without falling into the vague:

> ***Explain how* a given landform (e.g., mountain) has been shaped by processes that build up structures (e.g., uplift) and by processes that break down and carry away material (e.g., *weathering* and *erosion*). (grades 6-8)**

And the following general statement about plate tectonics is unique in mentioning the approximate rate of the motion:

> **The *crust* is composed of huge *crustal plates* on the scale of continents and oceans which move centimeters per year, pushed by *convection* in the upper *mantle*, causing earthquakes, volcanoes, and mountains. (grades 6-8)**

Representative of Washington's standards, this statement is rigorous but stumbles in that it opts for the general term "crust" instead of the correct "lithosphere."

Life Science

By far the strongest of the Washington standards are those for life science, which are thorough, well-explained, and grade-appropriate. For instance, Kindergartners and first-grade students are asked to:

> ***Compare* how different animals use the same body parts for different purposes (e.g., humans use their tongues to taste, while snakes use their tongues to smell). (grades K-1)**

And the physiology coverage through eighth grade is equally strong. (One important flaw is the complete lack of physiology coverage in high school.)

Evolution is covered well, too. The big idea devoted to biological evolution emerges in Kindergarten and first grade and continues from there, with a clear progression of content and rigor through the successive grades. In addition, there is significant coverage of fossils by fourth and fifth grades.

The standards also make the importance of evolution clear, specifically stating:

> **The scientific *theory* of *evolution* underlies the study of biology and explains both the *diversity* of life on Earth and similarities of all *organisms* at the chemical, cellular, and molecular level. *Evolution* is supported by multiple forms of scientific *evidence*. ...*Evidence* for *evolution* includes similarities among anatomical and cell structures, and *patterns* of development make it possible to *infer* degree of relatedness among *organisms*. (grades 6-8)**

The strong coverage of evolution continues in high school, as evidenced by the following:

> **Both the fossil record and analyses of DNA have made it possible to better understand the causes of variability and to determine how the many species alive today are related. Evolution is the major framework that explains the amazing diversity of life on our planet and guides the work of the life sciences. (grades 9-12)**

In addition, common ancestry, deep time, and other essential concepts are addressed well.

Without the total failure of physics and the near-total failure of chemistry, the Washington standards would fare reasonably well in content and rigor. Unfortunately, these major stumbles overwhelm the standards' glimmers of excellence and drag the state's score down to a three out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

At their best, the Washington standards contain statements that express critical content in crystal-clear prose. For instance, in the physical science material for grades six through eight we have:

> **Substances have *characteristic intrinsic properties* such as *density*, *solubility*, *boiling point*, and *melting point*, all of which are independent of the amount of the sample.**
>
> ***Students are expected to:***
>
> **Use *characteristic intrinsic properties* such as *density*, *boiling point*, and *melting point* to identify an unknown substance. (grades 6-8)**

Much of the rest of the document is similarly lucid and specific. But it is not perfect. As happens frequently in many states, an excellent set of standards is kneecapped by a truly dumb glossary. Consider some of the worst offenders in the Washington document:

> **Apply: The skill of selecting and using information in new situations or problems.**

As in "A good student acquires many applies"?

> **Chemical properties: Any of a material's properties, such as color, pH, or ability to react with other chemicals, that becomes evident during a chemical reaction.**

Of course, color is emphatically not a chemical property. And, as for pH, this implies that the chemical properties of HCl depend on its concentration, which is not true.

Sadly, these are the rule in the glossary, not the exception.

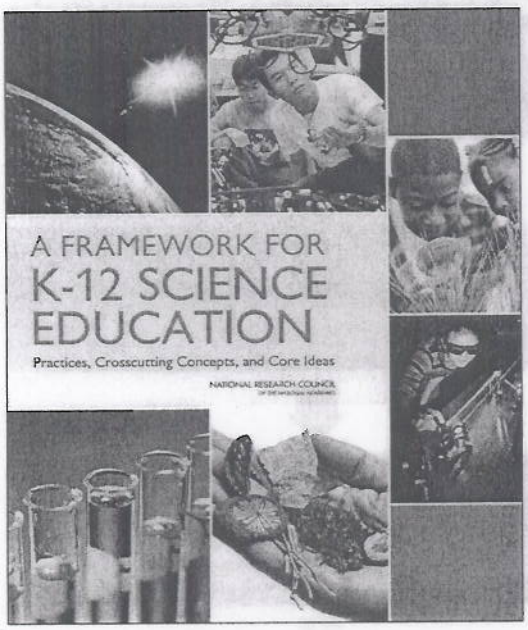
Omitting the silly glossary, however, the presentation and organization of the standards are generally top-notch. As such, they earn a solid three out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)

SCIENCE EDUCATION
AT THE NATIONAL RESEARCH COUNCIL
www.nationalacademies.org/bose

REPORT BRIEF • JULY 2011 • BOARD ON SCIENCE EDUCATION

A FRAMEWORK FOR K-12 SCIENCE EDUCATION:

PRACTICES, CROSSCUTTING CONCEPTS, AND CORE IDEAS



WHY IS A K-12 SCIENCE FRAMEWORK NEEDED?

Science, engineering, and technology permeate every aspect of modern life. Some knowledge of science and engineering is required to understand and participate in many major public policy issues of today, as well as to make informed everyday decisions, such as selecting among alternate medical treatments or determining whether to buy an energy-efficient furnace.

By the end of the 12th grade, students should have sufficient knowledge of science and engineering to engage in public discussions on science-related issues, to be critical consumers of scientific information related to their everyday lives, and to be able to continue to learn about science throughout their lives. They should recognize that our current scientific understanding of the world is the result of hundreds of years of creative human endeavor. And these are goals for *all* of the nation's students, not just those who pursue higher education or careers in science, engineering, or technology.

Today, science education in the United States is not guided by a common vision of what students finishing high school should know and be able to do in science. Too often, standards are long lists of detailed and disconnected facts, reinforcing the criticism that our schools' science curricula tend to be "a mile wide and an inch deep." Not only does this approach alienate young people, it also leaves them with fragments of knowledge and little sense of the inherent logic and consistency of science and of its universality. Moreover, the current fragmented approach neglects the need for students to engage in doing science and engineering, which is a key part of understanding science.

The time is ripe for a new framework for K-12 science education not only because of weaknesses in the current approaches, but also because new knowledge in both the sciences and the teaching and learning of science has accumulated in the past 15 years. In addition, the movement by most of the states to adopt common standards in mathematics and in language arts has prompted the call for comparable standards in science to guide state reforms.

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

National Academy of Sciences • National Academy of Engineering • Institute of Medicine • National Research Council

The National Research Council (NRC) of the National Academy of Sciences was asked to develop a framework that would provide unifying guidance for the nation's schools to improve all students' understanding of science. The expert committee that developed the framework used research-based evidence on how students learn, input from a wide array of scientific experts and educators, and past national reform efforts, as well as its members' individual expertise and collective judgment.

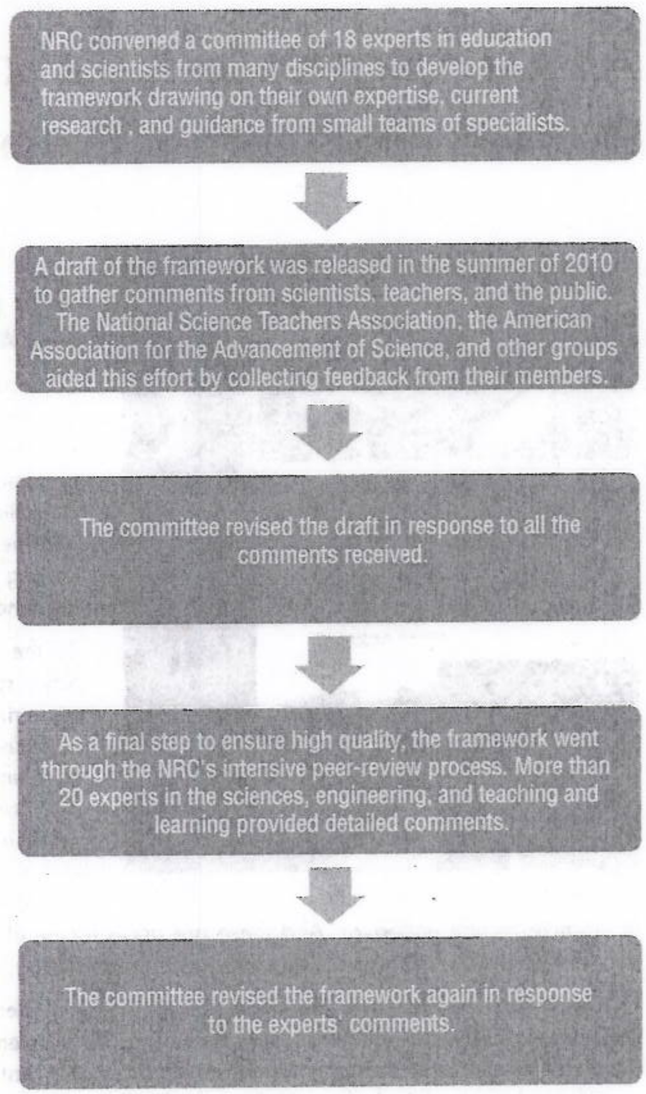
HOW WILL THE FRAMEWORK BE USED?

The framework is designed to be the basis for the next generation of science standards. Using the practices, crosscutting concepts, and core ideas that the framework lays out, a group of states, coordinated by Achieve, Inc. (a nonprofit education organization), will develop standards for what students should learn at different grade levels.

The framework is also designed to be useful to others who work in science education, including:

- curriculum developers and assessment designers;
- educators who train teachers and create professional development materials for them;
- state and district science supervisors, who make key decisions about curriculum, instruction, and professional development; and
- science educators who work in informal settings, such as museum exhibit designers or writers and producers of documentary films.

HOW THE FRAMEWORK WAS DEVELOPED



WHAT IS IN THE FRAMEWORK?

The framework consists of a limited number of elements in three dimensions: (1) scientific and engineering practices, (2) crosscutting concepts, and (3) disciplinary core ideas in science. It describes how they should be developed across grades K-12, and it is designed so that students continually build on and revise their knowledge and abilities throughout their school years. To support learning, all three dimensions need to be integrated into standards, curricula, instruction, and assessment.

DIMENSION 1:
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

This dimension focuses on important practices used by scientists and engineers, such as modeling, developing explanations or solutions, and engaging in argumentation. For example, all of the disciplines of science share a commitment to data and evidence as the foundation for developing claims about the world. As they carry out investigations and revise or extend their explanations, scientists examine, review, and evaluate their own knowledge and ideas and critique those of others through a process of argumentation. These practices have too often been underemphasized in K-12 science education.

Engaging in the full range of scientific practices helps students understand how scientific knowledge develops and gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. Similarly, engaging in the practices of engineering helps students understand the work of engineers and the links between engineering and science.

The full report describes these eight practices, articulating the major competencies that students should have by the end of 12th grade and outlining how student competence might progress across the grades.

DIMENSION 2:
CROSSCUTTING CONCEPTS THAT HAVE COMMON APPLICATION ACROSS FIELDS

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

The seven crosscutting concepts are key across science and engineering. They provide students with ways to connect knowledge from the various disciplines into a coherent and scientific view of the world. For example, the concept of "cause and effect: mechanism and explanation" includes the key understandings that events have causes, sometimes simple, sometimes multifaceted; that a major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated; and that such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Students' understanding of these crosscutting concepts should be reinforced by their repeated use in instruction across the disciplinary core ideas (see Dimension 3). For example, the concept of "cause and effect" could be discussed in the context of plant growth in a biology class and in the context of investigating the motion of objects in a physics class. Throughout their science and engineering education, students should be taught the crosscutting concepts in ways that illustrate their applicability across all the core ideas.

DIMENSION 3: CORE IDEAS IN FOUR DISCIPLINARY AREAS

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 framework includes core ideas for the physical sciences, life sciences, and earth and space sciences because these are the disciplines typically included in science education in K-12 schools. Engineering and technology are featured alongside these disciplines for two critical reasons: to reflect the importance of understanding the human-built world and to recognize the value of better integrating the teaching and learning of science, engineering, and technology.

The focus on a limited number of core ideas in science and engineering is designed to allow sufficient time for teachers and students to explore each idea in depth and thus with understanding.

The full report provides detailed descriptions of each core idea, as well as descriptions of what aspects of each idea should be learned by the end of grades 2, 5, 8 and 12. Establishing limits for what is to be learned about each core idea for each grade band clarifies the most important ideas that students should learn.

HOW CAN THE VISION OF THE FRAMEWORK BE REALIZED?

Students will make the greatest strides in learning science and engineering when all components of the system—from professional development for teachers to curricula and assessments to time allocated for these subjects during the school day—are aligned with the vision of the framework. Aligning the existing K-12 system with that vision will involve overcoming many challenges, including teachers' familiarity with new instructional practices and the time allocated to science. The full report identifies such challenges to help educators and policymakers begin to consider how to meet them. It also offers recommendations to guide standards developers and lays out a research agenda to inform updates of the framework and standards in the future.

COMMITTEE ON A CONCEPTUAL FRAMEWORK FOR NEW SCIENCE EDUCATION STANDARDS

HELEN R. QUINN *(Chair)*, Stanford Linear Accelerator Center, Stanford University; **WYATT W. ANDERSON**, Department of Genetics, University of Georgia, Athens; **TANYA ATWATER**, Department of Earth Science, University of California, Santa Barbara; **PHILIP BELL**, Learning Sciences, University of Washington, Seattle; **THOMAS B. CORCORAN**, Teachers College, Columbia University; **RODOLFO DIRZO**, Department of Biology, Stanford University; **PHILLIP A. GRIFFITHS**, Institute for Advanced Study, Princeton, New Jersey; **DUDLEY R. HERSCHBACH**, Department of Chemistry and Chemical Biology, Harvard University; **LINDA P.B. KATEHI**, Office of the Chancellor, University of California, Davis; **JOHN C. MATHER**, NASA Goddard Space Flight Center, Greenbelt, Maryland; **BRETT D. MOULDING**, Utah Partnership for Effective Science Teaching and Learning, Ogden; **JONATHAN OSBORNE**, School of Education, Stanford University; **JAMES W. PELLEGRINO**, Department of Psychology and Learning Sciences Institute, University of Illinois, Chicago; **STEPHEN L. PRUITT**, Office of the State Superintendent of Schools, Georgia Department of Education (until June, 2010); **BRIAN REISER**, School of Education and Social Policy, Northwestern University; **REBECCA R. RICHARDS-KORTUM**, Department of Bioengineering, Rice University; **WALTER G. SECADA**, School of Education, University of Miami; **DEBORAH C. SMITH**, Department of Curriculum and Instruction, Pennsylvania State University

National Research Council Staff: **HEIDI A. SCHWEINGRUBER**, Study Co-Director; **THOMAS KELLER**, Study Co-Director; **MICHAEL A. FEDER**, Senior Program Officer (until February 2010); **MARTIN STORKSDIECK**, Board Director; **KELLY A. DUNCAN**, Senior Program Assistant (until October 2010); **REBECCA KRONE**, Program Associate; **STEVEN MARCUS**, Editorial Consultant

For More Information . . .

This brief was prepared by the Board on Science Education www.nationalacademies.org/bose. Copies of the report, *A Framework for K-12 Science Standards: Practices, Crosscutting Concepts, and Core Ideas*, are available from the National Academies Press at (888) 624-8373 or (202) 334-3313 (in the Washington, DC metropolitan area) or via the National Academies Press webpage at www.nap.edu. The study was funded by the Carnegie Corporation. Any opinions, findings, conclusions, or recommendations expressed in the publication are those of the authors and do not necessarily reflect those of the Carnegie Corporation.

Related Titles

Successful K-12 STEM Education (2011)
Surrounded by Science (2010)
Engineering in K-12 Education (2009)
Learning Science in Informal Environments (2009)
Ready, Set, SCIENCE! (2008)
Taking Science to School (2007)
America's Lab Report (2006)
Systems for State Science Assessment (2006)

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

The nation turns to the National Academies—National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council—for independent, objective advice on issues that affect people's lives worldwide.
www.national-academies.org

NEXT GENERATION SCIENCE STANDARDS

Frequently Asked Questions

Purpose for the Standards
- Why new science standards? Why now?

Contents and Research Background of the Standards
- How will critical thinking and communications skills, which are fundamental to student success in today's global economy, be addressed in the Next Generation Science Standards?
- How will the standards take into account current research in cognitive science?
- Will the standards be internationally benchmarked?
- What are core ideas in science?
- What are scientific practices?
- What are crosscutting concepts?

Standards Development Process
- How is the development of the Next Generation Science Standards different than the development of the Common Core State Standards?
- Is the federal government sponsoring the development of the Next Generation Science Standards?
- Who will be involved in the development of the Next Generation Science Standards?
- Will there be an opportunity for the general public to submit feedback on the standards during the development process?
- What is the timeline for completing the Next Generation Science Standards?
- After the writing team completes its work, will there be an alignment of the Next Generation Science Standards to the National Research Council's Framework for K–12 Science Education?

Next Steps for the Standards and Framework
- Will the new standards be the Common Core State Standards for Science?
- How will states use these standards documents?
- How will states use the NRC's Framework?
- Will there be common science assessments?

Purpose of Next Generation Science Standards

Why new science standards? Why now?

Science—and therefore science education—is central to the lives of all Americans, preparing them to be informed citizens in a democracy and knowledgeable consumers. It is also the case that if the nation is to compete and lead in the global economy and if American students are to be able to pursue expanding employment opportunities in science-related fields, all students must all have a solid K–12 science education that prepares them for college and careers. States have previously used the National Science Education Standards from the National Research Council (NRC) and Benchmarks for Science Literacy from the American Association for the Advancement of Science (AAAS) to guide the development of their current state science standards. While these two documents have proven to be both durable and of high quality, they are around 15 years old. Needless to say, major advances have since taken place in the world of science and in our understanding of how students learn science effectively. The time is right to take a fresh look and develop Next Generation Science Standards.

Contents and Research Background of the Standards

How will critical thinking and communications skills, which are fundamental to student success in today's global economy, be addressed in the Next Generation Science Standards?

It is important to understand that the scientific practices defined by the NRC include the critical thinking and communication skills that students need for postsecondary success and citizenship in a world fueled by innovations in science and technology. These science practices encompass the habits and skills that scientists and engineers use day in and day out. In the Next Generation Science Standards these practices will be wedded to content. In other words, content and practice will be intertwined in the standards, just as they are in the NRC Framework and in today's workplace.

How will the standards take into account current research in cognitive science?

Research on how students learn science effectively has been a long-term interest of the National Research Council, which published How People Learn, How Students Learn, and most recently, Taking Science to School. Findings in cognitive science permeate the Framework for K–12 Science Education and will be central to developing the Next Generation Science Standards.

Will the standards be internationally benchmarked?

Yes. Achieve undertook a study of 10 countries' standards to determine their overall emphases in the expectations they have for all students (grade spans 1–6 and 7–10), as well as emphases in Biology, Chemistry, Physics and Earth/Space courses in upper secondary. The comparison countries were generally those whose students performed well on the Programme for International Student Assessment (PISA) or the Trends in International Math and Science Study (TIMSS): Ontario Canada, Chinese Taipei, England, Finland, Hong Kong, Hungary, Ireland, Japan, Singapore and South Korea. Achieve's study consisted of two parts: a quantitative analysis of the knowledge and performances included in each country's standards; and a qualitative in-depth review of five of the ten countries that offered the most guidance for constructing useful and meaningful standards.

The quantitative analysis enabled Achieve to detect patterns of emphases in major categories of knowledge and performances. Major findings for grade span 1-10 were as follows: Seven of 10 countries require general science for all students through grade 10, prior to students taking discipline-specific courses; Physical science (chemistry and physics taken together) receives the most attention; Biology receives somewhat less attention, and Earth/space science much less; Crosscutting content, such as the nature of science and engineering, and the interactions of science, technology and society, and environmental sustainability also receives significant attention. Achieve's qualitative analysis revealed exemplary features that we hope to incorporate in the Next Generation Science Standards, such as: the use of an overarching conceptual framework; multiple examples to clarify the level of rigor expected and connect concepts with applications; concrete links between standards and assessments; and development of inquiry and design processes in parallel to facilitate students engaging in both science and engineering practices. (Additional information regarding the study can be found at www.Achieve.org.)

What are core ideas in science?

The NRC defines disciplinary core ideas as those that focus K–12 science curriculum, instruction and assessments on the most important aspects of science disciplinary content knowledge. In order to identify the relevant core ideas for K–12 level science, the NRC Framework Committee developed and applied a set of criteria. To be considered "core", the ideas should meet at least two of the following criteria and ideally all four: Have broad importance across multiple sciences or engineering disciplines or be a key organizing principle of a single discipline; Provide a key tool for understanding or investigating more complex ideas and solving problems; Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge; Be teachable and learnable over multiple grades at increasing levels of depth and sophistication. Design teams working in four domains – life sciences, physical sciences, earth and space sciences, and engineering and technology – supported the work of the committee on core ideas, examining related research and key documents. These included recent research on teaching and learning science, much of which has been summarized in previous reports from the NRC—How People Learn, Taking Science to School, Learning Science in Informal Environments, Systems for State Science Assessment and America's Lab Report. The Committee and design team members also reviewed the NAEP 2009 Science Framework, the College Board Science Standards for College Success, NSTA's Science Anchors initiative, and such seminal documents as the National Science Education Standards developed by the NRC and the Benchmarks for Science Literacy developed by AAAS.

What are scientific practices?

Scientific practices are the behaviors that scientists engage in as they investigate and build models and theories about the natural world. The NRC uses the term practices instead of a term like "skills" to emphasize that engaging in scientific inquiry requires coordination of both knowledge and skills simultaneously. Use of the term practices helps avoid the interpretation of skill as rote mastery of an activity or procedure. Part of the NRC's intent is to better explain and extend what is meant by "inquiry" in science and the range of cognitive, social, and physical practices that it requires.

Like previous editions of science standards from the NRC and AAAS, science practices will also include practices of engineering, which are the behaviors that engineers engage in as they apply science and mathematics to design solutions to problems. Although engineering design is similar to scientific inquiry there are significant differences. For example, scientific inquiry involves the formulation of a question that can be answered through investigation, while engineering design involves the formulation of a problem that can be solved through design. Strengthening the engineering aspects of the Next Generation Science Standards will clarify for students the relevance of science, technology, engineering and mathematics (the four STEM fields) to everyday life. And engaging in these practices help students become successful analytical thinkers, prepared for college and careers.

What are crosscutting concepts?

The NRC Framework describes crosscutting concepts as those that bridge disciplinary boundaries, having explanatory value throughout much of science and engineering. Crosscutting concepts help provide students with an organizational framework for connecting knowledge from the various disciplines into a coherent and scientifically based view of the world. These are as follows: Patterns; Cause and effect: Mechanism and explanation; Scale, proportion and quantity; Systems and system models; Energy and matter: Flows, cycles, and conservation; Structure and function; Stability and change. The Framework also emphasizes that these concepts need to be made explicit for students because they provide an organizational schema for interrelating knowledge from various science fields into a coherent and scientifically-based view of the world.

Standards Development Process

How is the development of the Next Generation Science Standards different than the development of the Common Core State Standards?

The Next Generation Science Standards (NGSS) is following a different developmental pathway than did the Common Core State Standards (CCSS) in English language arts and mathematics. The process for the science standards development takes into account the importance of having the scientific and educational research communities identify core ideas in science, articulate them across grade bands, and provide on-going advice throughout the process. That is why the NRC took the first step by constructing a Framework for K–12 Science Education—to ensure scientific validity and accuracy. A committee of 18 experts in science, engineering, cognitive science, teaching and learning, curriculum, assessment and education policy, was responsible for writing the Framework. The Framework describes a vision of what it means to be proficient in science; it rests on a view of science as both a body of knowledge and an evidence-based, model and theory building enterprise that continually extends, refines, and revises knowledge. It also presents and explains the interrelationships among practices, cross-disciplinary concepts and disciplinary core ideas. The NRC released a draft for public comment during the summer of 2010 and the final report in July of 2011.

Achieve will facilitate the next step: a state-led process where state policy leaders, higher education, K–12 teachers, the science and business community and others will develop science standards that are grounded in the Framework. This second step recognizes the importance of state and educator leadership in the development of the actual standards. Moreover, all stakeholders can expect that there will be multiple opportunities for public feedback, review and discussion just as there were in the CCSS process.

Is the federal government involved in the development of the Next Generation Science Standards?

No. The federal government is not involved in this effort. It is state-led, and states will decide whether or not to adopt the standards. The work undertaken by both the NRC and Achieve is being supported by the Carnegie Corporation of New York. No federal funds have or will be used to develop the standards.

Who will be involved in the development of the Next Generation Science Standards?

The development of the Standards will be a state-led effort. In addition to states, the NRC, the National Science Teachers Association (NSTA), AAAS, and other critical partners such as the Council of Chief State School Officers (CCSSO), the Council of State Science Supervisors (CSSS), and the National Governors Association (NGA) will be active in the development and review of the new standards and will provide significant strategic support to states. Writing and review teams will consist of K–12 teachers, state science and policy staff, higher education faculty, scientists, engineers, cognitive scientists, and business leaders.

Will there be an opportunity for the general public to submit feedback on the standards during the development process?
Yes. The Next Generation Science Standards will have two public web-based feedback periods prior to the finalization of the standards. In addition, state leaders, teachers, scientific and educator organizations, higher education faculty, scientists and business community members will review drafts at specific intervals.

What is the timeline for completing the Next Generation Science Standards?
The current timeline is designed to complete the standards by fall 2012.

Will there be an alignment of the Next Generation Science Standards to the National Research Council's Framework for K–12 Science Education?
During development, a feedback loop between Achieve and the National Academies will ensure fidelity of the standards to the Framework.

Next Steps for the Standards and Framework

Will the new standards be the Common Core State Standards for Science?
In the end, the decision to adopt the standards will lie in the hands of the states themselves. The goal is to create robust K–12 science standards that all states can use to guide teaching and learning in science for the next decade. Thus, the National Academies, Achieve, NSTA, and AAAS are working collaboratively with states and other stakeholders to help ensure the standards will be of high quality—internationally benchmarked, rigorous, research-based and aligned with expectations for college and careers.

How will states use these standards documents?
To reap the benefits of the science standards, states should adopt them in whole, without alteration. States can use the NGSS, as they are using the CCSS in English language arts and mathematics, to align curriculum, instruction, assessment, and professional preparation and development.

How will states use the NRC Framework?
The NRC Framework articulates a vision for science learning and teaching. States can start implementing changes to their systems for professional development and pre-service teacher training based on a deep understanding of this vision. They can also begin to think about ways to align curriculum, instruction and assessment with this vision. Once the Next Generation Science Standards are developed, the process of alignment can begin in earnest.

Will there be science assessments aligned to the NGSS?
States will decide whether to create common assessments aligned to the Next Generation Science Standards.

Developing Next Generation Science Standards

Overview

Through a collaborative, state-led process, new K–12 science standards are being developed that will be rich in content and practice, arranged in a coherent manner across disciplines and grades to provide all students an internationally benchmarked science education. The *Next Generation Science Standards* will be based on the *Framework for K–12 Science Education* developed by the National Research Council. The NGSS should be completed in late 2012.

Background

There is no doubt that science—and, therefore, science education—is central to the lives of all Americans. Never before has our world been so complex and science knowledge so critical to making sense of it all. Whether it is comprehending current events, choosing and using technology or making informed decisions about one's healthcare, science understanding is key. Science is also at the heart of the United States' ability to continue to innovate, lead and create the jobs of the future. All students—from technicians in a hospital to workers in a high tech manufacturing facility to Ph.D. researchers—must have a solid K–12 science education.

It has been 15 years since science standards have been comprehensively reviewed. The National Research Council's *National Science Education Standards* and the American Association for the Advancement of Science's *Benchmarks for Science Literacy*, while critical to the field for the past 15 years, do not reflect the changes we have experienced in society or science, such as the availability of the internet, access to cell phones, and even the changes within science such as the emergence of biotechnology and changes of how we see our own solar system (for example, Pluto). Needless to say, a lot has happened in the world of science and our knowledge of science learning in 15 years. In addition, there has been a significant amount of research into how students learn science. The time is right to take a fresh look at science standards.

Step One: Getting the Science Right

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 *Next Generation Science Standards*. The National Research Council (NRC), the functional staff arm of the National Academy of Sciences, began the process by developing the *Framework for K–12 Science Education*, which was published in July 2011. The *Framework* is a critical first step because it is grounded in the most current research on science and science learning and will identify the science all K–12 students should know. To undertake this effort, the NRC convened a committee of 18 individuals who are nationally and internationally known in their respective fields. The committee included practicing scientists, including two Nobel laureates, cognitive scientists, science education researchers, and science education standards and policy experts. In addition, the NRC used four design teams to develop the framework. These four design teams, in physical science, life science, earth/space science, and engineering, developed the framework for their respective disciplinary area. The NRC released a public draft in July of 2010 and considered all feedback prior to releasing the final Framework.

Step Two: States Developing Next Generation Science Standards

In a process managed by Achieve, states will lead the development of rigorous and internationally-benchmarked science standards that will be faithful to the *Framework*. These *Next Generation Science Standards*, will be developed through collaboration between states and other stakeholders in science, science education, higher education, business and industry. Additional review and guidance will be provided by advisory boards composed of nationally-recognized leaders in science, science education as well as business and industry. As part of the development process, the standards will undergo multiple reviews from many stakeholders including two public drafts, allowing all who have a stake in science education an opportunity to inform the proposed content and organization of the standards. This process will produce a set of excellent, K–12 *Next Generation Science Standards* ready for state adoption. Whether individual states decide to adopt them and whether they become consistent between the states will ultimately be up to the states themselves.

Process for Developing Next Generation Science Standards

Next Generation Science Standards development work will begin with *State teams,* which will provide confidential and continuous feedback throughout the development process. States are strongly encouraged to involve representation of the K–12 education, education policy, scientific, post-secondary education, and informal science communities. All states were invited to apply to be one of the Lead Partner States, which will take a leadership role in the NGSS process from the beginning. The Lead Partner States will guide the writing team and will also work together to develop plans for adoption, implementation and transition that can be considered by other states.

The *writing team*, composed of 40 members from 26 states, represents states, K–12 and postsecondary education, and the scientific, engineering, and business communities. The members will have expertise in cognitive, life, earth, and physical sciences and engineering. The writing team is charged with creating draft standards true to the NRC *Framework* and will do so in a process that takes into account feedback from states and stakeholders.

In addition to the state teams and writers there will be a *critical stakeholder team* of hundreds of members, representing K–12 educators, administrators, higher education faculty, scientists, engineers, business leaders, policymakers, and key organizations. This team will provide confidential feedback at critical points in the development process. In addition to these established teams and feedback loops, there will be opportunities for *public review*. The standards will be released for public comment twice during the development process before the final document is released.

Timeline

The release of the *Next Generation Science Standards* is expected in Fall 2012, with public drafts available in winter 2011/12 and summer of 2012.

The development of the *Framework for K–12 Science Education* and the *Next Generation Science Standards* is supported by the Carnegie Foundation.

NEXT GENERATION SCIENCE STANDARDS

Timeline

Throughout the development process, the *Next Generation Science Standards* (NGSS) will go through several rounds of review with multiple stakeholder groups. Each group will receive draft standards at least twice throughout the development process. Below is the general process and timeline for the development of the NGSS.