Next Generation Science Standards: Good or Bad for Science Education? †*

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ABSTRACT

According to information at the *Next Generation of Science Standards* (NGSS) site <http://bit.ly/Wwgjka>, "the *Common Core State* Standards (CCSS) were written to help students meet the particular challenges of reading, writing, speaking, listening, and language in their respective fields." . . . . . . [[Pro and con opinions on CCSS are set forth in "The Contentious Common Core Controversy" [Hake (2013b)] at <http://bit.ly/Y7ocMv> and "The Contentious Common Core Controversy #2 " [Hake (2013c)] at <http://bit.ly/Wtj62R>]] . . . . . . In contrast, the NGSS "will lay out the core ideas and practices in science that students should master in preparation for college and careers." A side-by-side comparison of similarities and differences of CCSS and NGSS is given in "Conceptual Framework for Science Education and the Next Generation Science Standards" [Pruitt (2012a)] at <http://1.usa.gov/10wb4Yv>. The second draft of NGSS was released on 8 January 2013, and the final version is scheduled for this month, March 2013.

At <http://bit.ly/YPwB7j> the American Association of Physics Teachers (AAPT) has criticized the second draft, stating that the "wording of many of the NGSS performance expectations is confusing to the point that it is not clear what students are actually supposed to do," and that "the science content of the current form of NGSS contains so many errors that most science teachers and scientists will doubt the credibility of the entire enterprise."

At <http://bit.ly/XvHuPS>, Janet Coffey and Bruce Alberts delineate the *Good* and the *Bad* in the second draft: ***Good***: "[NGSS] builds on *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* at <http://bit.ly/zy0qqG> [which puts] forth a vision of science education that is notable for emphasizing student participation in key science and engineering practices, such as asking questions and defining problems; developing and using models; engaging in argument from evidence; and learning cross-cutting concepts such as energy and matter, cause and effect, and structure and function. To allow room for these in the school day, the *Framework* stressed the importance of minimizing the number of disciplinary core ideas that standards require to be taught. ***Bad***: " . . . . . the sheer volume of content referenced in the framework moves to the foreground in the NGSS draft and threatens to undermine this promise. . . . . Urgently needed is a vigorous R&D agenda that pursues new methods of and approaches to assessment. . . . . . A systematic commitment to the wrong quantitative measures, such as the inexpensive multiple-choice testing of factoids, may well result in the appearance of gains at the tremendous cost of suppressing important aspects of learning, attending to the wrong things in instruction, and conveying to students a distorted view of science."

It remains to be seen whether or not the above deficiencies will be overcome in the final version of NGSS.

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† The reference is: Hake, R.R. 2013a. "*Next Generation Science Standards*: Good or Bad for Science Education?" 18 March, online as ref. 68 at <http://bit.ly/a6M5y0>.

*Within quotes: (a) my emphasis is shown by *italics*, and (b) my inserts are shown as ". . . . [[insert]]. . . .".

 Partially supported by NSF Grant DUE/MDR-9253965.

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At the "Frequently Asked Question" (FAQ) section <http://bit.ly/Wwgjka> of the NGSS site <http://bit.ly/y1gJPx> one of the FAQs (QB7 in the list below in Section VIIB2) is:

"What is the difference between the *Common Core State Standards* for Literacy in Science and the NGSS?" The answer given is as follows:

AB7."The CCSS Literacy Standards were written to help students meet the particular challenges of reading, writing, speaking, listening, and language in their respective fields-in this case, science. The literacy standards do not replace science standards-they supplement them. The NGSS will lay out the core ideas and practices in science that students should master in preparation for college and careers."

A side-by-side comparison of similarities and differences of CCSS and NGSS is given by Achieve's Stephen Pruitt in "Conceptual Framework for Science Education and the Next Generation Science Standards" at <http://1.usa.gov/10wb4Yv>.

II. Recent Developments on the NGSS Effort

The second and evidently final draft of the *Next Generation Science Standards* (NGSS) was released in January 2013 and is available online at NGSS (2013) <http://bit.ly/Z2V8YS>. There it's stated:

"Thank you for your feedback on the second draft of the Next Generation Science Standards. The standards are now being revised based on your feedback, and will be available on this webpage once they are completed in March of 2013."

Education Week's Erik Robelen (2013a,b,c) has reported on recent developments on the NGSS effort. In his January 8 piece "New Science-Standards Draft Includes Many Changes" at <http://bit.ly/10neMU1> Robelen (2013a) wrote:

"A second and final public draft of common standards [NGSS (2013)] aimed at reshaping K-12 science education was released today for comment, following eight months of review and rewriting. Organizers emphasized that the latest version reflects substantial changes from the draft issued last May, with a clear focus on taking to heart feedback gathered from more than 10,000 individuals and organizations. 'It's pretty different from the last draft, significantly so,' said Stephen L. Pruitt <http://bit.ly/WbDyTI>, a vice president at the Washington nonprofit Achieve <http://bit.ly/WkjC39>, which is overseeing the development of the *Next Generation Science Standards*. 'Ninety-five percent of performance expectations have been changed since May in some way'."

And in the 12 Feb 2013 entry "Chemistry, Physics, Biology Groups Respond to Science Standards" <http://bit.ly/XWNrUM> of his blog "Curriculum Matters," Robelen (2013c) wrote:

"Does chemistry get enough attention in the latest draft of common science standards? Are the performance expectations for students clearly written and easy to understand? And what about this whole business of integrating engineering across science disciplines? These are a few of the issues raised by reviewers from several content-specific groups I recently contacted, including the American Chemical Society <http://bit.ly/14zBhSx>, the American Physical Society <http://bit.ly/ZjKADd>, and the National Association of Biology Teachers <http://bit.ly/VMwU7t>. All found things to like and some areas for concern. A second and final public draft of the standards came out last month, with the final product expected in March. The standards are being developed by 26 "lead state partners". . . . . . [[see <http://bit.ly/YPF4Y6>]]. . . . in collaboration with experts in science and science education."

III. NGSS Writing Team And Critical Stakeholders

A. Writing Team

A list of the 41 members of the NGSS writing team is online at <http://bit.ly/XZWV1E>. It includes biologist Rodger Bybee <http://bit.ly/ZxPi1y>; chemist Melanie Cooper <http://bit.ly/ZmAGk8>; science-education specialists Richard Duschl <http://bit.ly/Y0Li8k>, Joseph Krajcik <http://bit.ly/13KjaNS>, and Okhee Lee <http://bit.ly/15CKYlC>; engineers Bob Friend <http://bit.ly/15CMoN2> and Mike McQuade <http://bit.ly/WQ9YAl>; physicist Ramon Lopez <http://bit.ly/13LB6Ii>; science and technology specialist Peter McLaren <http://bit.ly/12ARZFL>; geophysicist Michael Wysession <http://bit.ly/Y1yiBB>; and many elementary, middle, and high school teachers/administrators/supervisors.

B. Critical Stakeholders

A list of hundreds of "Critical Stakeholders" is online at <http://bit.ly/13Kq45H>, prefaced by the following:

"Critical Stakeholders are distinguished individuals and organizations that represent education, science, business and industry and who have interest in the *Next Generation Science Standards*. The members are drawn from all 50 states and have expertise in:

1. Elementary, middle and high school science from both urban and rural communities;
2. Special education and English language acquisition;
3. Postsecondary education;
4. State standards and assessments;
5. Cognitive science, life science, physical science, earth/space science, and engineering/technology;
6. Mathematics and Literacy;
7. Business and industry;
8. Workforce development;
9. Education policy.

The Critical Stakeholders will critique successive, confidential drafts of the standards and provide feedback to the writers and states, giving special attention to their areas of expertise."

IV. Criticism of the Second Draft of the NGSS

A. American Association of Physics Teachers (AAPT)

Criticism of the second draft, lodged by the American Association of Physics Teachers (AAPT) is online with an introduction at AAPT (2013a) <http://bit.ly/YPwngr> and a summary of the report at AAPT (2013b) <http://bit.ly/YPwB7j>. The Executive Summary of the latter is [bracketed by "AAPT-AAPT-AAPT- . . . . ." ; my *italics*; my inserts at ". . . . . . [[insert]] . . . . . "]:

AAPT-AAPT-AAPT-AAPT-AAPT-AAPT-AAPT-AAPT-AAPT

On January 28, 2013, the American Association of Physics Teachers (AAPT) convened a group of fourteen physicists, physics teachers, and educational specialists to review and comment on the January 2013 draft of the *Next Generation Science Standards* (NGSS). *The group was disappointed with that draft of NGSS and found that significant editorial changes, if not a whole new formulation, will be needed before AAPT and the broader science community can support that document as the basis for national K-12 science education standards*. There are several major difficulties with the current NGSS:

(1) The NGSS Student Performance Expectations are built on the articulation of Science and Engineering Practices and on Disciplinary Core Ideas as articulated in the National Research Council report *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* [[NAP (2012a) at <http://bit.ly/zy0qqG>]]. . . . . Although we applaud the link between practices and core ideas, *A Framework* has several statements of disciplinary core ideas that are unclear and *some that are scientifically inaccurate*. Unfortunately, NGSS has inherited those flawed statements.

(2) We argued in our May 2012 response to the first draft of NGSS. . . . .[[AAPT (2012) at <http://bit.ly/YPvPHn>]]. . . . .that it is a *strategic error of enormous magnitude to associate only one of the science and engineering practices with one disciplinary core idea*. As a matter of science standards, students should be expected to be able to perform any of the practices with any of the disciplinary core ideas. We are in essence urging that NGSS not define precisely which practice would be assessed with which disciplinary core idea. Teachers may want to assess one cluster of practices in their classrooms, others might be assessed by district or state tests, and yet others by nationally normed assessments. The performance standards should be separated from the details of the assessment tools, which should build on, but should not dictate, performance expectations.

(3) The *wording of many of the NGSS performance expectations is confusing to the point that it is not clear what students are actually supposed to do*.

(4) *The science content of the current form of* NGSS *contains so many errors that most science teachers and scientists will doubt the credibility of the entire enterprise*. In what follows, we cite evidence from NGSS to support these conclusions, we give examples of how to reconstruct the performance expectations that make them more understandable as well as being scientifically correct, and we propose what AAPT will do in conjunction with other teachers, science educators, scientists and scientific societies to produce documents that can be used to move forward the nationwide science standards effort.

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B. National Science Teachers Association (NSTA)

Criticism of the second draft lodged by the National Science Teachers Association (NSTA) is online at <http://bit.ly/12xXCEO>. Some excerpts are as follows [bracketed by "NSTA-NSTA- NSTA- . . . . . ; my *italics*; my inserts at ". . . . . . [[insert]] . . . . . "]:

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1. Importance of the Foundation Box

NSTA recommends that the NGSS lead states and writers emphasize that the fundamental aspects of NGSSs learning goals reside in the foundation box, and that the performance expectations are to be used at the conclusion of instruction to assess student learning. NSTA views the foundation box as paramount for those teaching and planning instruction.

. . . .[[I could not locate the "foundation box" at NGSS (2013a) <http://bit.ly/Z2V8YS>. A Google search for [NGSS "foundation box"] (with the quotes but without the square brackets turned up "How to Read the *Next Generation Science Standards* at NGSS (2013b) <http://bit.ly/VU2hga>, containing a figure titled "Example 1: DCI Coding and Arrangement" which shows "foundation boxes (containing Practices, Disciplinary Core Ideas, and Crosscutting Concepts).]] . . . .

2. Inclusion of the Nature of Science

NSTA applauds the NGSS lead states and writers for making the nature of science more prominent in the second public draft, but *recommends a fuller integration of these important concepts into the standards to ensure they are a part of student outcomes*. . . . .

3. Addressing the Size and Scope of the Standards

NSTA appreciates that the NGSS lead states and writers pruned the content in the second public draft, but *recommends that they continue to prune ideas and/or shift them to higher grade levels to ensure the final document contains an achievable description of what all students should learn*.. . . . .

4. Implementing the Standards

NSTA recommends that the NGSS lead states and writers *include guidance on the time and resources necessary to implement the new science standards*.

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C. Janet Coffey and Bruce Alberts

A thoughtful critique of NGSS titled "Improving Education Standards" [Coffey & Alberts (2013)], pointing out the *good* and the *bad* of NGSS has been published <http://bit.ly/XvHuPS> in the 1 Feb 2013 issue of *Science* by Janet Coffey <http://bit.ly/YRGPUA> and Bruce Alberts <http://bit.ly/XYDXt4>. They wrote [bracketed by lines "C&A-C&A-C&A-. . . . ."; my *italics*; my inserts at ". . . . . . [[insert]] . . . . . "]:

C&A-C&A-C&A-C&A-C&A-C&A-C&A-C&A-C&A
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. . . . [[**The Good**]]. . . . This month, Achieve. . . . . [[<http://bit.ly/WkjC39>]] . . . . , an organization established by the 50 U.S. state governors to improve academic standards and testing, will begin finalizing its draft document (released in January 2013) of the *Next Generation Science Standards* (NGSS). . . . . . [[NGSS (2013a) at <http://bit.ly/Z2V8YS>]] . . . . . This document aims to establish new common standards for science education for students aged 5 to 18 in the United States, and it explicitly builds on. . . . . . [[*A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NAP, 2012a) at <http://bit.ly/zy0qqG>]]. . . . . . . The *Framework* put forth a vision of science education that is notable for emphasizing student participation in key science and engineering practices, such as asking questions and defining problems; developing and using models; engaging in argument from evidence; and learning cross-cutting concepts such as energy and matter, cause and effect, and structure and function. To allow room for these in the school day, the *Framework* stressed the importance of minimizing the number of disciplinary core ideas that standards require to be taught. Now that the NGSS document has entered its final revision stage, it is important to ask how well these standards match the powerful vision for them that was laid down by the *Framework*.

There is much to be commended in the draft. In particular, its emphasis on science and engineering practices could lay the groundwork for productive shifts toward helping students understand how science helps us make sense of the natural world, instead of just what science has learned.

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. . . . **[[The Bad**]]. . . . *But the sheer volume of content referenced in the framework moves to the foreground in the NGSS draft and threatens to undermine this promise*. Any emphasis on practices requires a science-rich conceptual context, and certainly the core ideas and cross-cutting concepts presented are useful here. However, the draft contains a vast number of core disciplinary ideas and sub-ideas, leaving little or no room for anything else. In the three grades of middle school (ages 11 to 13) alone, the NGSS draft specifies more than twice the disciplinary content than did the 1996 *National Science Education Standards*. . . . . . . [[(NAP, 1996) at <http://bit.ly/jSuaQD>]] . . . . . Thus, before finalizing the new standards, we urge Achieve to quickly convene small groups of the nation's best teachers at the primary, middle-school, and high-school levels. Although teachers have been involved in the writing effort . . . . . .[[see the list of the 41 members of the NGSS writing team, online at <http://bit.ly/XZWV1E>]] . . . . , their new charge should be to bring ground truth to the NGSS by determining the maximum number of disciplinary core ideas that can be covered in a single school year, while still leaving time for a productive focus on practices and cross-cutting ideas. And scientists should immediately be charged with prioritizing the disciplinary core ideas in the current draft (and their performance expectations) to reduce them to a more feasible number.

The welcome shift in priorities to teaching science and engineering practices along with the content brings an assessment challenge. The NGSS draft document addresses this challenge by delineating many performance expectations. However, *current measurements and approaches do not allow these types of performances to be assessed easily*; it is much more difficult to evaluate the quality of such engagement than to determine the accuracy of an explanation or a word definition. *Urgently needed is a vigorous R&D agenda that pursues new methods of and approaches to assessment*. This will be difficult but critically important long-term work. A systematic commitment to the wrong quantitative measures, such as the *inexpensive multiple-choice testing of factoids*, may well result in the appearance of gains at the tremendous cost of suppressing important aspects of learning, attending to the wrong things in instruction, and conveying to students a distorted view of science. Outstanding scientists must be willing to work side by side with measurement specialists and science educators to develop methods for evaluating what is important to measure, after completing the short-term task of prioritizing and reducing the number of disciplinary core concepts in the new standards. .

. . . . . [[C&A may be unaware of "Concept Inventories" <http://bit.ly/dARkDY> - see e.g., "The Impact of Concept Inventories on Physics Education and It's Relevance for Engineering Education" (Hake, 2011b) at <http://bit.ly/nmPY8F>]]. . . . . .

C&A-C&A-C&A-C&A-C&A-C&A-C&A-C&A-C&A

V. Commentary on *A Framework For K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* [NAP (2012b) at <http://bit.ly/zy0qqG>.

A. "Framework for New K-12 Science Education Standards" [DBASSE/BOSE (2012)] at <http://1.usa.gov/WuWQ8T>.

B. "New from the National Academies: 'A Framework for K-12 Science Education'" [Hake (2011)] at <http://bit.ly/Z2P1Cp>.

C. "A Framework for K-12 Science Education" [Quinn (2011)] at <http://bit.ly/WrQ0kp>.

D. "Science Education Shift: A new educational framework swaps breadth of scientific disciplines for depth and emphasizes the process of science" [Scudellari (2011)] at <http://bit.ly/ob3rFo>.

E. 'The NSTA Reader's Guide to *A Framework for K–12 Science Education, EXPANDED EDITION: Practices, Crosscutting Concepts, and Core Ideas* [Pratt et al. (2012)] at <http://bit.ly/15Gr2yg>.

VI. Commentary on NGSS

A. "Preparing Chemistry Teachers for the *Next Generation Science Standards*" [Bodner (2011)] at <http://bit.ly/ZiQubc>.

B. "The next generation of science standards: Implications for biology education" [Bybee (2012)] at <http://bit.ly/YI8WZB>.

C. "The *Next Generation Science Standards* and the Life Sciences: The important features of life science standards for elementary, middle, and high school levels" [Bybee (2013)] at <http://bit.ly/XvLz6V>.

D. "*Next Generation Science Standards*: Latest information on the Conceptual Framework and on the development of the *Next Generation Science Standards*" [CA-Education (2013)] at <http://bit.ly/YNrB2U>.

E. "The second dimension—crosscutting concepts: Understanding a framework for K–12 science education" [Duschl (2012)] at <http://bit.ly/ZxgbF0>.

F. "The science class of the (not too distant) future" [Martin (2012)] at <http://bit.ly/ZuRMxz>.

G. "National Association of State Boards of Education Launches *Next Generation Science Standards* Policy Initiative" [NASBE (2013) at <http://bit.ly/XVNtgE>.

H. "Conceptual Framework for Science Education and the *Next Generation Science Standards*, [Pruitt (2012a)] at <http://1.usa.gov/10wb4Yv>.

I. "Stephen Pruitt on the *Next Generation Science Standards*" [Pruitt (2012b)] at <http://bit.ly/15CxhDm>.

J. "New Classroom Science Standards Up for Review" [Revkin (2012)] at <http://nyti.ms/YHd2jJ>.

K. "Unifying Science Education Standards: Proposed framework for K–12 education aims for depth over breadth" [Widener (2012)] at <http://bit.ly/Y1OZwQ>.

L. "Exploring the new standards: How to form a study group to examine the *Next Generation Science Standards,* second public draft" [Willard, Pratt, & Workosky (2012)] at <http://bit.ly/ZmQsz6>.

VII. Further Information on NGSS:

A. Wikipedia entry <http://bit.ly/WZ3aG6>

B. NGSS website <http://bit.ly/y1gJPx> [my insertion of URLs]:

1. Statement on Nature of NGSS

"Through a collaborative, state-led process managed by "Achieve" <http://bit.ly/WkjC39>, 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 NGSS will be based on the *Framework for K–12 Science Education*' . . . . .[[NAP (2012b)]] at <http://bit.ly/zy0qqG>]]. . . . developed by the National Research Council."

2. Frequently Asked Questions & Answers,

Aside from the answer (AB7) given above in Section I to Question B7 (QB7) "What is the difference between the *Common Core State Standards* for Literacy in Science and the NGSS?" of particular interest are these Questions (Q) and Answers (A). Below I simply repeat information at the "Frequently Asked Question" (FAQ) section <http://bit.ly/Wwgjka> of the NGSS site but with these differences: (a) standard outline formatting is utilized; (b) references and remarks are inserted at ". . . . . . [[jnsert]] . . . . . "; (c) *Next Generation Science Standards* is replaced by "NGSS."

A. PURPOSE FOR THE STANDARDS

QA1. Why new science standards? Why now?

AA1. 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). . . . . . . [[NAP (1996)]]. . . . . . and "Benchmarks for Science Literacy" from the American Association for the Advancement of Science (AAAS). . . . . . .[[AAAS (1993)]]. . . . . . 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* . . . . . [[henceforth replaced by "NGSS"]] . . . . . .

B. CONTENTS AND RESEARCH BACKGROUND OF THE STANDARDS

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QB1: How will critical thinking and communications skills, which are fundamental to student success in today's global economy, be addressed in the NGSS?

AB1. 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 NGSS 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". . . . . [[NAP (2012b)]]. . . . . and in today's workplace.

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QB2. How will the standards take into account current research in cognitive science?

AB2. Research on how students learn science effectively has been a long-term interest of the National Research Council, which published "How People Learn" [Bransford, Brown, & Cocking (2000), "How Students Learn History, Mathematics, and Science In The Classroom. [Donovan & Bransford (2005)], and most recently, "Taking Science to School" [Duschl, Schweingruber, & Shouse (2007)]. Findings in cognitive science permeate the "Framework for K–12 Science Education". . . . . .[[NAP (2012b)]] . . . . and will be central to developing the NGSS.

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QB3. Will the standards be internationally benchmarked?

AB3. 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) . . . . . [[<http://bit.ly/10cEBm1> . . . . . .]] or the Trends in International Math and Science Study (TIMSS) . . . . . [[<http://1.usa.gov/12xhlVb>]] . . . .: 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 NGSS 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 <http://www.achieve.org/>.)

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QB4. What are core ideas in science?

AB4. 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: (1) Have broad importance across multiple sciences or engineering disciplines or be a key organizing principle of a single discipline; (2) Provide a key tool for understanding or investigating more complex ideas and solving problems; (3) Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge; (4) Be teachable and learnable over multiple grades at increasing levels of depth and sophistication.

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QB5. What are scientific practices?

AB5. 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 NGSS 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.

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QB6. What are crosscutting concepts?

AB6. 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

> . . . . [[Quoting from "Towards Coherence in Science Instruction: A Framework for Science Literacy" [Schmidt et al. (2011)]: "The NSF supported an effort to articulate a set of fundamental science concepts for organizing and providing coherence to K-8 science instruction as a part of the 'Promoting Rigorous Outcomes in Mathematics/Science Education (PROM/SE)'. . . . . . The idea informing this approach was that a small number of key concepts that govern the natural world that transcend or *cut across* the various science disciplines might serve to limit the number of essential topics."
>
> > There's little indication that the second draft, NGSS (2013), benefitted from the PROM/SE effort.]] . . . .

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QB7. What is the difference between the *Common Core State Standards* for Literacy in Science and the NGSS?

AB7. As indicated in Section I above: "The CCSS Literacy Standards were written to help students meet the particular challenges of reading, writing, speaking, listening, and language in their respective fields-in this case, science. The literacy standards do not replace science standards-they supplement them. The NGSS will lay out the core ideas and practices in science that students should master in preparation for college and careers."

C. STANDARDS DEVELOPMENT PROCESS
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QC1. How is the development of the NGSS different than the development of the *Common Core State Standards*?

AC1. The 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 and articulate them across grade bands. That is why the NRC took the first step by constructing a *Framework for K-12 Science Education* . . . . . [[NAP (2012b) at <http://bit.ly/zy0qqG>.]]. . . . . . - 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 names and affiliations of the 18 experts are listed on page v of NAP (2012b) at <http://bit.ly/zy0qqG>]]. . . . . . . The Framework describes a vision of what it means to be proficient in science. 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.

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QC2. Is the federal government sponsoring the development of the NGSS?

AC2. 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. . . . . . . [[<http://bit.ly/16sbmjw>]]. . . . . . No federal funds have or will be used to develop the standards.

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QC3. Who will be involved in the development of the NGSS ?

AC3. The development of the Standards will be a state-led effort. In addition to states, the NRC . . . . [[[<http://bit.ly/VLrvgR>]]. . . . . . ., the National Science Teachers Association (NSTA) . . . . . [[<http://bit.ly/W8trPl>]]. . . . . ., AAAS . . . . . .[[<http://bit.ly/XYtTxa>]]. . . . ., and other critical partners 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. Achieve will manage the development process on behalf of the lead states.

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QC4. Will there be an opportunity for the general public to submit feedback on the standards during the development process?

AC4. Yes. The NGSS 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.

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QC5. What is the timeline for completing the NGSS?

AC5. The current timeline is designed to complete the standards by the end of 2012. . . . . [[That anticipated timeline was optimistic. The final standards are now anticipated in March 2013,]] . . . .

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QC6. Will there be an alignment of the NGSS to the National Research Council's "Framework for K–12 Science Education?"

AC6. During development, a feedback loop between Achieve and the National Academies will ensure fidelity of the standards to the Framework.

D. NEXT STEPS FOR THE STANDARDS AND FRAMEWORK

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QD1. Will the new standards be the *Common Core State Standards* for Science?

AD1. In the end, the decision to adopt the standards and make them consistent between states will lie in the hands of the states themselves. The goal is to create robust, forward-looking 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.

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QD2. How will states use these standards documents?

AD2.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.

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QD3. How will states use the NRC's "Framework"?

AD3. The NRC Framewor*k* 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 NGSS are developed, the process of alignment can begin in earnest.

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QD4. Will there be science assessments aligned to the NGSS?

AD4. States will decide whether to create assessments aligned to the NGSS. 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 NGSS are developed, the process of alignment can begin in earnest.

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The book uses exemplary teaching to illustrate how approaches based on what we now know result in in-depth learning. This new knowledge calls into question concepts and practices firmly entrenched in our current education system. Topics include: 1. How learning actually changes the physical structure of the brain. 2. How existing knowledge affects what people notice and how they learn. 3. What the thought processes of experts tell us about how to teach. 4. The amazing learning potential of infants. 5. The relationship of classroom learning and everyday settings of community and workplace. 6. Learning needs and opportunities for teachers. 7. A realistic look at the role of technology in education."
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Successful K-12 STEM Education defines a framework for understanding 'success' in K-12 STEM education. The book focuses its analysis on the science and mathematics parts of STEM and outlines criteria for identifying effective STEM schools and programs. Because a school's success should be defined by and measured relative to its goals, the book identifies three important goals that share certain elements, including learning STEM content and practices, developing positive dispositions toward STEM, and preparing students to be lifelong learners. A successful STEM program would increase the number of students who ultimately pursue advanced degrees and careers in STEM fields, enhance the STEM-capable workforce, and boost STEM literacy for all students. It is also critical to broaden the participation of women and minorities in STEM fields.

Successful K-12 STEM Education examines the vast landscape of K-12 STEM education by considering different school models, highlighting research on effective STEM education practices, and identifying some conditions that promote and limit school- and student-level success in STEM. The book also looks at where further work is needed to develop appropriate data sources. The book will serve as a guide to policy makers; decision makers at the school and district levels; local, state, and federal government agencies; curriculum developers; educators; and parent and education advocacy groups.

See also *Monitoring Progress Toward Successful K-12 STEM Education: A Nation Advancing*? [NAP (2012a)].

NAP. 2012a. *Monitoring Progress Toward Successful K-12 STEM Education: A Nation Advancing*? online at <http://bit.ly/Xg39eN>. The "Description" reads:

"Following a 2011 report . . . . . [[NAP (2011)]] . . . . . by the National Research Council (NRC) on successful K-12 education in science, technology, engineering, and mathematics (STEM), Congress asked the National Science Foundation to identify methods for tracking progress toward the report's recommendations. In response, the NRC convened the Committee on an Evaluation Framework for Successful K-12 STEM Education to take on this assignment. The committee developed 14 indicators linked to the 2011 report's recommendations. By providing a focused set of key indicators related to students' access to quality learning, educator's capacity, and policy and funding initiatives in STEM, the committee addresses the need for research and data that can be used to monitor progress in K-12 STEM education and make informed decisions about improving it.

The recommended indicators provide a framework for Congress and relevant deferral agencies to create and implement a national-level monitoring and reporting system that: assesses progress toward key improvements recommended by a previous National Research Council (2011) committee; measures student knowledge, interest, and participation in the STEM disciplines and STEM-related activities; tracks financial, human capital, and material investments in K-12 STEM education at the federal, state, and local levels; provides information about the capabilities of the STEM education workforce, including teachers and principals; and facilitates strategic planning for federal investments in STEM education and workforce development when used with labor force projections. All 14 indicators explained in this report are intended to form the core of this system. *Monitoring Progress Toward Successful K-12 STEM Education: A Nation Advancing?* summarizes the 14 indicators and tracks progress towards the initial report's recommendations."

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"Science, engineering, and technology permeate nearly every facet of modern life and hold the key to solving many of humanity's most pressing current and future challenges. The United States' position in the global economy is declining, in part because U.S. workers lack fundamental knowledge in these fields. To address the critical issues of U.S. competitiveness and to better prepare the workforce, *A Framework for K-12 Science Education* proposes a new approach to K-12 science education that will capture students' interest and provide them with the necessary foundational knowledge in the field. *A Framework for K-12 Science Education* outlines a broad set of expectations for students in science and engineering in grades K-12. These expectations will inform the development of new standards for K-12 science education and, subsequently, revisions to curriculum, instruction, assessment, and professional development for educators. This book identifies three dimensions that convey the core ideas and practices around which science and engineering education in these grades should be built. These three dimensions are: crosscutting concepts that unify the study of science through their common application across science and engineering; scientific and engineering practices; and disciplinary core ideas in the physical sciences, life sciences, and earth and space sciences and for engineering, technology, and the applications of science. The overarching goal is for all high school graduates to have sufficient knowledge of science and engineering to engage in public discussions on science-related issues, be careful consumers of scientific and technical information, and enter the careers of their choice. *A Framework for K-12 Science Education* is the first step in a process that can inform state-level decisions and achieve a research-grounded basis for improving science instruction and learning across the country. The book will guide standards developers, teachers, curriculum designers, assessment developers, state and district science administrators, and educators who teach science in informal environments."

An 'Important Notice" reads: "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*. **Step One: Getting The Science Right** The National Research Council began by developing the 'Framework for K-12 Science Education.' The 'Framework' is a critical first step because it is grounded in the most current research on science and science learning and identifies the science all K-12 students should know. **Step Two: States Developing *Next Generation Science Standards*** In a process managed by 'Achieve', states will lead the development of K-12 science standards, rich in content and practice, arranged in a coherent manner across disciplines and grades to provide all students an internationally-benchmarked science education. The NGSS will be based on the 'Framework' and will prepare students for college and careers."

The Authoring Organizations are the:

a. Board on Science Education (BOSE) <http://bit.ly/ZR58Zy>
b. Behavioral and Social Sciences and Education (DBASSE) <http://bit.ly/15nPSTo>

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> "Thank you for your feedback on the second draft of the Next Generation Science Standards. The standards are now being revised based on your feedback, and will be available on this webpage once they are completed in March of 2013. All of the materials released for the second public draft review period were working drafts and were removed from the website during the revision period. The NGSS are composed of the three dimensions <http://bit.ly/Zij38E> from the NRC Framework [NAP (2012b)]. Click on the links to the left to learn more about the standards."

Contains a video with testimonials from various supporters.

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> "With common standards in science set to be finalized in March, states will soon face the dilemma of embracing them as their own or going their own way, raising the question of how common the Next Generation Science Standards will ultimately prove to be. The 26 "lead state partners" <http://bit.ly/YPF4Y6> helping to develop the K-12 standards have agreed to "give serious consideration" to adopting them. Recent interviews with officials in a number of those states, such as California, Delaware, Kansas, and Maryland, reveal a generally positive reaction to the second and final public draft, issued this month for comment. Meanwhile, some other states that are not lead partners are closely tracking the process and even have assembled broad-based teams to provide feedback along the way. Officials in both Florida and Louisiana, for instance, say their states. . . . ."

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> "A review of state science standards [Lerner (2012)] released in January by the nonprofit Thomas B. Fordham Institute gave the majority of states a D or F. The review evaluated whether the state standards were clear enough to be used by teachers, whether they covered the material thoroughly, and whether they were scientifically correct. "You had different states with different levels of expectations for their kids," said Pruitt, a former science supervisor in Georgia.
>
> For many reasons, this diversity in state standards has created problems for those who are trying to improve science education. "You didn't have an opportunity for states to collaborate, to share assessment, to share professional development," says Peter J. McLaren, president of the Council of State Science Supervisors and a science supervisor in Rhode Island. For example, he can't discuss testing or curriculum with surrounding states, Massachusetts and Connecticut."

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