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State Science Education Standards Comparison Tool

Purpose and Audience

This tool is intended for use as a companion to a standards crosswalk comparison, and allows users to gain a more thorough understanding of the similarities and differences between two sets of state science education standards that would not otherwise be captured when only making a more traditional content comparison. Typical state standards crosswalk-style documents focus on a one-to-one comparison of discipline-specific science content between sets of standards. Because new science standards documents, including the Next Generation Science Standards (NGSS), differ greatly in structure, complexity and intent from other existing sets of standards, these one-to-one content comparisons might not fully capture the extent of the differences between standards. By working through the questions in this tool, users should be better able to identify how standards compare on various aspects of knowledge development.

Due to the broad and inclusive nature of the questions, this tool is also useful as a learning resource. While simply reading the answers in a completed questionnaire can be helpful to new users, the act of preparing answers to at least one or two of the questions will provide users with a much deeper understanding of each set of standards and of the comparisons between them. And because the answers each user provides may vary depending on his/her experiences and role (e.g., state board of education members, administrators and teachers), different stakeholder groups should independently answer at least one question whenever possible. The incorporation of multiple perspectives will further enhance the depth of understanding of the differences between the sets of standards compared.

Intended User

Ideally, individual(s) who use the tool should have some familiarity with both sets of standards being compared, including an understanding of the formats (e.g., which parts are assessable and which are supplementary). Primary users are likely to be staff members of a state education agency, but the tool might also be of interest to state board of education members, district administrators, teachers, and developers of instructional materials or assessments.

Because it is crucial that any standards comparison process be transparent and unbiased, when the questionnaire is used at a state or district level, it may be necessary to involve independent parties outside the state's internal standards review team, such as higher education faculty members, researchers, business leaders and others who are respected by the decision makers and their constituents.

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Usage and Language

This comparison tool is intended to produce evidence for discussion regarding similarities and differences between sets of standards and the presentation of these standards to various audiences. This tool and the answers produced should not be relied upon to serve as the primary means of information delivery to the intended audience (e.g., board of education, school committee, etc.). Once the comparison is complete and all users have had a chance to provide answers to the questions, this tool could then inform a more formal report or presentation that details the significant findings.

When developing a comparison and presentation for decision makers, keep in mind the connotations of language choices. As much as possible, language used should be nontechnical, neutral with regard to any particular set of standards, and applicable to both sets of standards in the comparison. The focus should be on a comparison of the components in each set of standards — not on the particular words used to describe the components.

Due to the differences between this tool's comparisons and a typical crosswalk document, avoid using the term *crosswalk* when describing the results of this tool. Some states have successfully used the terms *comparison*, *alignment,* or *analysis* in presentations.

Structure

The tools is designed as a table with rows containing suggested categories for comparison and columns listing the standards to be compared. For each set of standards, there is one column for a description of how those standards address the question in each row and a second column to cite the location of evidence from those standards that supports that description.

Category	Question	STANDARDS A:		STANDARDS B:*Next Generation Science Standards (2013)* *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	Evidence from Standards A to Support the Answer	How Do Standards B Address the Question?	Evidence from Standards B to Support the Answer

When considering a question, users should give details of exactly how the information in the standards answers the question and then list specifically where in the standards documents this information can be found. This design is intended to help users make broad, conceptual comparisons about the intent of each of two sets of standards, particularly in places where a focused, detailed one-to-one comparison would fall short. The focus on documenting evidence for each answer also will help users gather evidence to support adoption and implementation decisions regarding state science education standards.

The structure of the tool can be customized for a particular situation or context. For example, rows can be expanded to include greater detail in areas of particular state importance (e.g., the inclusion of engineering design). In addition, “Standards A” and “Standards B” can represent any two sets of science standards — the prepopulated NGSS columns can be replaced with other sets of standards when appropriate.

Identifying Opportunities for Direct Comparison Between Sets of Standards

There are many different ways to compare different sets of standards. As a companion to traditional content crosswalks, this tool is intended to focus on conceptual comparisons between sets of state standards. In addition, there are some instances where a direct comparison of individual standards is useful. These direct comparisons resemble the one-to-one content comparisons of more traditional crosswalk documents, but have a different purpose. Direct comparisons of standards with similar components in this case are meant to highlight similarities and differences in the specificity and demands of different sets of standards.

Kansas 2007 Science Education Standards, Grades 8–11, Biology, HS.3.3.4	NGSS Life Sciences Grades 9–12, HS-LS3-3
“The student understands organisms vary widely within and between populations.”	“Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.”

Direct comparison between standards of similar content but different structure or design can be challenging, especially with standards that have a multidimensional design (e.g., the NGSS). A direct comparison can be done, for example, by comparing the verbs used in each statement. Above is a sample comparison between a learning outcome from Kansas’ previous Science Education Standards (Kansas adopted the NGSS as their new state science education standards in June 2013) and a related NGSS performance expectation.

Comparing the verbs in two statements of similar content helps illustrate the different level of student synthesis and depth of knowledge required, as well as the differences in the specificity of standards with respect to what it means to “meet” each standard. Such a comparison also can help highlight similarities and differences in equity and issues of access as well as other qualitative differences between the standards. These specific comparisons should be chosen based on relevance to the state’s education needs and decision makers’ priorities.

Other methods of direct comparison between standards include but are not limited to the following: (a) mapping aligned assessment or instructional items to one another or to the other set of standards; (b) comparing a standard in one set to the “nearest neighbor” in the other standards document; and (c) if a nearest neighbor does not exist, writing a comparable standard modeled after the verbs and architecture found in the standard of interest. These direct comparisons between standards can be used together with the results of this questionnaire and with a content crosswalk to get a full view of the differences between two sets of standards.

Development Process and Acknowledgements

The state science standards comparison tool was conceptualized and drafted by a team of experts in science education and state education standards, including:

Rachel Aazzerah, Science Assessment Specialist, Oregon Department of Education
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Michael Heinz, Science Coordinator, New Jersey Department of Education
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Matt Krehbiel, Science Program Consultant, Kansas Department of Education
Mary Lord, State Board Member, District of Columbia
Peter McLaren, Science Specialist, Rhode Island Department of Education
William Penuel, Professor of Learning Sciences, University of Colorado Boulder

The draft tool was submitted to states for pilot testing and feedback. Revisions were then made to the tool based on the pilot test results and user feedback.

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General Information on Standards Development and Design

The development and use of standards in education typically follow an education model where the standards are statements of what students are supposed to have learned and be able to do by the end of their instructional experience, and these statements are used to guide the development of all components of the education system (Resnick and Zurawsky, 2005).

Standards can be used to guide the development of curriculum plans, instructional units and assessment, with assessment measuring whether curriculum and instruction are producing the measured achievement stated in the standards (Clune, 2001; NRC, 2006; Resnick and Zurawsky, 2005). Standards are designed to apply to all learners and set a high bar for student achievement, and all students are expected to meet the standards. It is recommended that multiple instructional and assessment strategies be developed to meet the needs of each student, allowing every student to achieve the standards.

General Information on Standards Development and Design	Question	STANDARDS A: How Do Standards A Address the Question?	STANDARDS A: Evidence from Standards A	STANDARDS B: *Next Generation Science Standards (2013)* How Do Standards B Address the Question?	STANDARDS B: *Next Generation Science Standards (2013)* Evidence from Standards B
	What process was used to develop the standards, including what research and background materials (NSES, etc.) are the standards documents based on?			The NGSS were developed in a state-led process. Twenty-six states signed on to be Lead State Partners. The states provided guidance and direction in the development of the NGSS to the 41-member writing team, composed of K–20 educators and experts in both science and engineering. In addition to six reviews by the lead states and their committees, the NGSS were reviewed during development by hundreds of experts during confidential review periods and by tens of thousands of members of the general public during two public review periods. The NGSS content and structure are based on the National Research Council's Framework for K–12 Science Education (2012a), and an NRC review found that the NGSS were faithful to the NRC Framework. Both the Framework and the NGSS were also based on Achieve's International Science Benchmarking work, which compared the standards of 10 countries.	NGSS Introduction (NGSS Lead States, 2013, Vol. I, p. xvi), www.nextgenscience.org/lead-state-partners, www.nextgenscience.org/writing-team, www.nextgenscience.org/critical-stakeholders, National Research Council Review of the Next Generation Science Standards (NGSS Lead States, 2013, Vol. I, p. v), International Science Benchmarking Report (Achieve, 2010)

General Information on Standards Development and Design	Question	**<u>STANDARDS A:</u>**		**<u>STANDARDS B:</u>** ***Next Generation Science Standards (2013)***	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	What part(s) of the science standards is required of all high school students, and to what extent do these fit the time restrictions of a typical school year?			The NGSS focus on a limited number of core ideas in science and engineering that build coherently over time throughout K–12 in an effort to foster a greater depth of understanding of a few fundamental concepts within the constraints of the typical school year (Vol. II, pp. 40, 113–115). **These standards are expected of all students, including at the high school level,** with opportunity for accelerated students to continue past the requirement of the standards (Vol. II, pp. 25, 31, 114). However, having expectations for all students does not mean that all students will take the same courses in high school. There are many different ways to structure different courses (e.g. CTE courses, integrated science, senior project, etc.) that could help different students reach and exceed proficiency on the standards.	Appendix D (NGSS Lead States, 2013, Vol. II, pp. 25–39), Appendix E (NGSS Lead States, 2013, Vol. II, pp. 40–47), Appendix K (NGSS Lead States, 2013, Vol. II, pp. 113–136)

Research on the Nature of Science and Methods of Inquiry in Science

Learning about science involves more than just learning facts and concepts; it involves learning about how scientists view the world (e.g., habits of mind and modes of thought), how scientific knowledge is developed (e.g., processes of questioning, investigation, data collection and data analysis), and how the different scientific disciplines are connected in describing the natural world (AAAS, 1989, pp. 1–12; Lederman, 1992; McComas et al., 1998). Aspects of the nature of science, including components of scientific inquiry, could be explicitly integrated with science content in the standards to give students a deeper appreciation for how scientific knowledge is developed, which enhances the depth of content learning (Clough, 1998; Khisfe and Lederman, 2006; Lederman and Lederman, 2004; McComas and Olson, 1998; McDonald, 2010; NRC, 1996, pp. 105, 107, Table 6.7; NRC, 2002a, pp. 18–20, Tables 2.2, 2.3; Schwartz et al., 2004; Songer and Linn, 1991). Also, highlighting in the standards important overarching themes of science that apply to all scientific disciplines (e.g. systems, models, consistency and change, scale, etc.) and more content-specific core concepts shared by more than one discipline helps students to develop a greater depth of understanding by allowing them to consider a single, fundamental scientific theme/concept in different disciplinary contexts (AAAS, 1989, pp. 165–181; Georghiades; 2000; Helfand, 2004; Hestenes, 2013; Ivanitskaya et al., 2002; Jacobson and Wilensky, 2006; Jordan, 1989; Mathison and Freeman, 1998; NRC, 1996, p. 104; NRC, 2012a, pp. 83–101; Parsons and Beauchamp, 2012, pp. 157–173).

Components of scientific inquiry can specifically be incorporated with the content in the standards by including student expectations such as understanding and using subject-specific vocabulary; individual and collaborative investigation; building models, sketches and diagrams; critical analysis of a text or an argument; evidence-based argumentation and explanation; making predictions; developing and testing hypotheses; computation; using tables and graphs to interpret and present data; and communicating scientific findings and ideas in multiple forms (AAAS, 1989, pp. 1–12; Anderson, 2002; Haury, 1993; Llewellyn, 2006, p. 27; Minner et al., 2010; NRC, 1996, p. 105, Table 6.1; NRC, 2002a, pp. 18–20, 115–120, Tables 2.2, 2.3; NRC, 2005, pp. 397–415).

Students will have the greatest potential to develop deep understanding of science content and of the nature of science when they can engage in the material covered by the standards through a variety of learning avenues (Magnusson et al., 1999, Table II, p. 101; Minner et al., 2010; NRC, 1996, p. 105; NRC, 2002a, pp. 115–124; Zirbel, 2006). Providing room for such flexibility of learning in the standards gives students opportunities to encounter or apply science content in different, typically novel settings (i.e., learning transfer) and benefits all students because the content can be tailored to students with different learning styles, motivations and cultural backgrounds (Felder and Brent, 2005; Felder and Silverman, 1988; Georghiades, 2000; NRC, 1999, pp. 62–68; NRC, 2002a, pp. 119–120, 126; Tanner and Allen, 2004).

Nature of Science and Methods of Inquiry in Science	Question	**<u>STANDARDS A:</u>**		**<u>STANDARDS B:</u>** ***Next Generation Science Standards (2013)***	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	How is the nature of science represented in the standards?			The NGSS include eight student "Understandings about the Nature of Science" (Vol. II, p. 97) in each K–12 grade band. These are described in detail in Appendix H (Vol. II, pp. 96–102) and are incorporated in the practices and crosscutting concepts foundation boxes throughout the standards wherever they are used in the student performance expectations; for an example, see HS-ESS1 (Vol. I, p. 121). The first four nature of science themes describe student experiences within the scientific and engineering practices dimension, and the next four themes describe student understanding within the crosscutting concepts dimension (Vol. II, pp. 97–99).	Appendix H (NGSS Lead States, 2013, Vol. II, pp. 96–102)

Nature of Science and Methods of Inquiry in Science	Question	**<u>STANDARDS A:</u>**		**<u>STANDARDS B:</u>** ***Next Generation Science Standards (2013)***	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	What aspects of scientific inquiry and processes (e.g., skills and habits of mind) are expressed in the standards, and how are they related to or integrated with the content?			The NGSS are written as performance expectations built from the three dimensions described in the NRC Framework (2012a), including science practices (Vol. II, p. 48). These eight practices are the behaviors that scientists engage in as they investigate and build models and theories about the natural world: asking questions; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations; engaging in argument from evidence; and obtaining, evaluating, and communicating information. The practices are integrated with the disciplinary core ideas and crosscutting concepts in every NGSS performance expectation; students are expected to demonstrate their understanding of the core ideas and crosscutting concepts in the context of the practices. For an example, see HS-ESS1 (Vol. I, pp. 119–121).	Appendix F (NGSS Lead States, 2013, Vol. II, pp. 48–78)

Nature of Science and Methods of Inquiry in Science	Question	STANDARDS A:		STANDARDS B: *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	How are the interconnections in scientific content among individual scientific disciplines (e.g., chemistry, life sciences, physical sciences, earth sciences, etc.) expressed in the standards?			The NGSS express interconnections among scientific disciplines in two distinct ways. First, crosscutting concepts are one of the three NRC Framework (2012a) dimensions from which the NGSS performance expectations were developed. Crosscutting concepts are ideas that have applicability across all science disciplines and that serve to deepen student understanding of each discipline (Vol. II, p. 79). They are integrated into each performance expectation so students demonstrate their understanding of the disciplinary core ideas and practices in the context of the crosscutting concepts. For an example, see HS-ESS1 (Vol. I, pp. 119–121). The progression in expectations of student performance on the crosscutting concepts through the grade levels is also described in detail in Appendix G (Vol. II, pp. 79–95). The NGSS also express interconnections in another way. "Connection boxes" are present with each set of student performance expectations, providing suggestions for interdisciplinary connections that could be made when implementing the NGSS. For example, teachers could help students connect the topic of gravity in physical sciences (HS-PS2-4 and HS-PS2.B, Vol. I, pp. 94–96, 155) to similar topics in earth and space sciences (HS-ESS1-4 and HS-ESS1.B, Vol. I, pp. 119–121, 160).	Appendix G (NGSS Lead States, 2013, Vol. II, pp. 79–95)

Nature of Science and Methods of Inquiry in Science	Question	STANDARDS A:		STANDARDS B: *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	In what ways do the standards encourage students to use multiple avenues of learning (e.g., learning by doing, direct instruction, reading, etc.) and to apply content material in novel situations?			The performance expectations are not a curriculum and do not dictate methods of instruction. Instead, they are statements of what students should know and be able to do at the end of each grade band (in middle and high school) and each grade level (in elementary school) (Vol. I, p. xxiii). The performance expectations can and should be met through a number of different means (e.g., Vol. II, p. 101), allowing for multiple avenues of learning for diverse student groups (Vol. II, p. 35) as well as encouraging innovation and creativity in instruction. Importantly, the integration of science and engineering practices into the performance expectations in the NGSS ensures that students will be expected to demonstrate proficiency in many different kinds of skills, thereby increasing the likelihood that instruction will incorporate many different kinds of learning modes.	Appendix D (NGSS Lead States, 2013, Vol. II, pp. 25–39), Appendix F (NGSS Lead States, 2013, Vol. II, pp. 49–50)

Research on Connections/Relationships Among Standards at Different Grade Levels

Research on the retention and depth of understanding of science content indicates that learning is enhanced through repeated and varied engagement with the content (NRC, 1999, pp. 20, 51–78; NRC, 2001, pp. 84–88; NRC, 2007, pp. 211–249). The coverage of a greater number of concepts that are sequentially introduced from grade level to grade level leads to a shallow understanding of each of those concepts, whereas the repetition of fewer concepts that are considered fundamental and that increase in sophistication with grade level leads to a deeper understanding of those concepts (e.g., learning progressions; Corcoran et al., 2009; Duschl et al., 2011; Kesidou and Roseman, 2002; NRC, 2007, pp. 211–216; NRC, 2008, pp. 59–85; Schmidt et al., 2005; Smith et al., 2006). By focusing on fewer concepts, there is the opportunity to investigate those concepts with methodology consistent with current scientific inquiry and processes, which also leads to greater knowledge transfer (Grabinger and Dunlap, 1995; Lavonen and Laaksonen, 2009).

In instances where the science standards are coherent, with science concepts introduced gradually and then deliberately built upon from grade level to grade level (i.e., curriculum coherence), there are quantified increases in learning (e.g., higher test scores and increased performance at the college level; Bao et al., 2009; NRC, 2007, p. 216; Schmidt et al., 2005; Schwartz et al., 2008; Valverde and Schmidt, 2000). Because the progressive building of a few fundamental concepts over time leads to a deeper understanding of those concepts, every standard at every grade level that addresses a concept is essential to understanding the learning goals in subsequent years.

Connections/Relationships Among Standards at Different Grade Levels	Question	**<u>STANDARDS A:</u>**		**<u>STANDARDS B:</u>** ***Next Generation Science Standards (2013)***	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	In what ways are the standards designed to build from grade level to grade level in science content, depth of content understanding and the application of scientific inquiry and processes?			The NGSS focus on a limited number of core ideas in science and engineering that build coherently over time throughout K–12 (Vol. II, pp. 41–47, disciplinary core idea progression charts), such that by the end of high school all students are expected to have developed an accurate and thorough understanding of each core idea. The depth of understanding appropriate for each grade band was specified by the NRC Framework (2012a). Student performance expectations at each grade band form a foundation for the achievement of the next grade band's associated performance expectation(s). Practices and crosscutting concepts also grow in complexity and sophistication across the grades (Vol. II, pp. 49–67, practices tables; Vol. II, pp. 80–88 crosscutting concept tables), allowing for a greater depth of understanding of the core ideas and crosscutting concepts over time, as well as a greater mastery of science and engineering practices.	Appendix E (NGSS Lead States, 2013, Vol. II, pp. 40–47), Appendix F (NGSS Lead States, 2013, Vol. II, pp. 48–78), Appendix G (NGSS Lead States, 2013, Vol. II, pp. 79–95)

Connections/Relationships Among Standards at Different Grade Levels	Question	**<u>STANDARDS A:</u>**		**<u>STANDARDS B:</u>** ***Next Generation Science Standards (2013)***	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	If there are any "outlier concepts" within the standards, how might they relate back to or reinforce the other concepts in the standards?			The NGSS are standards for all students and focus on a limited number of core ideas in science (Vol. II, p. 40). These core ideas were derived from the NRC Framework (2012a) and met the Framework committee's criteria for inclusion in expectations for all students. To ensure that the NGSS scope was teachable and that there can be time in a typical classroom to help all students build depth of understanding in these core ideas, the NGSS do not include concepts that fall outside the direct progression to each core idea. However, the NGSS should not be viewed as a ceiling for instruction. Students who are proficient in the NGSS can and should go beyond the standards to make connections and apply what they have learned to other areas of interest.	Appendix E (NGSS Lead States, 2013, Vol. II, pp. 40–47)

Research on the Evaluation of Understanding and Application of Content Knowledge

The progression from novice to expert in science involves more than just acquisition of rote content knowledge. Experts are able to identify patterns, solve problems, and make connections in ways that reflect a deep understanding of the content (NRC, 1999, pp. 31–50; NRC, 2012b, pp. 78–79, 84–86). Research indicates that deep learning of science content, particularly content that is related to complex, multidisciplinary systems, is best achieved when students have multiple opportunities to engage in a few key foundational concepts over a sustained period of time in many different and authentic contexts (Grabinger and Dunlap, 1995; Jacobson and Wilensky, 2006; NRC, 1999, pp. 51–78; NRC, 2002b, pp. 117–129; NRC, 2008, pp. 59–85; NRC, 2012a, pp. 24–27; NRC, 2012b, pp. 69–85, 125–129, 136–137; Zirbel, 2006).

Deep learning of material "is more difficult when a concept is taught in a limited set of contexts or through a limited set of activities" (NRC, 2002, pp. 127–128) because students miss the applicability of the concept to real life problems and other classes or disciplines (Grabinger and Dunlap, 1995). It is only by encountering the same concept in multiple ways, particularly in novel contexts, that the student can develop a depth of understanding and demonstrate true knowledge transfer (Georghiades, 2000; NRC, 2002a, pp. 116, 119–120; NRC, 2002b, pp. 117–129). Varying the contexts in which students encounter a given concept, and allowing opportunities for application and connections to other disciplines, helps build and deepen student knowledge of scientific concepts (Kuhn et al., 1992; NRC, 2002b, pp. 117–129).

In addition, learning and a depth of understanding are enhanced when the concepts are applied in authentic contexts where the activity uses methods similar to those currently practiced in science and engineering (Ainsworth, et al., 2011; Dym et al., 2005; Keys, 1999; McNeill, 2011; Mehalik et al., 2008; NRC, 2007, pp. 149–159; Osborne, 2010; Rivard, 1994; Schauble et al., 1995; Zimmerman, 2007). Students who build and use the skills and methods in which scientists engage will be developing hypotheses, using experimentation and observation to build evidence, participating in position-driven discussion, citing evidence in explanations and arguments, and using visual representations when explaining scientific findings and phenomena (AAAS, 1989, pp. 1–12; Lederman, 1992; McComas et al., 1998). By engaging in the methods of science, students will also learn more about the nature of science and confront their misconceptions about how science is done (NRC, 2007, pp. 168–178). They will learn to construct and defend an explanation without ignoring, distorting, or selectively choosing evidence; without confusing belief for evidence; and without changing the hypothesis to fit the evidence (NRC, 2007, pp. 131–142). They will also develop an understanding and appreciation that science is an human endeavor, something that people do and create, done through collaboration and cooperation that involves creativity and comes to a consensus of content knowledge through the persuasiveness of evidence (NRC, 2007, pp. 168–178).

	Question	STANDARDS A:		STANDARDS B: *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	Evidence from Standards A	How Do Standards B Address the Question?	Evidence from Standards B
Evaluation of Understanding and Application of Content Knowledge	In what ways do the standards encourage students to apply content knowledge or to use content knowledge in novel situations to build and demonstrate depth of understanding?			Decades of science education research have indicated that the best way to help students learn content deeply is to provide opportunities to practice applying content material, particularly in novel situations (Grabinger and Dunlap, 1995). By building the performance expectations from the three dimensions described in the NRC Framework (2012a), the NGSS require application of a relevant practice of science or engineering with a core disciplinary idea(s) and connecting a crosscutting concept(s) with that core idea. Through the repeated application of the science and engineering practices and crosscutting concepts to different core ideas (especially among different disciplines) and through the explicit connections between core ideas in different performance expectations, the students are expected to use core ideas in different and novel contexts, which enhances depth of understanding of all three of the dimensions (Vol. II, pp. 49–50, 80–81). In addition, many performance expectations throughout K–12 explicitly describe engineering applications for core ideas.	Appendix F (NGSS Lead States, 2013, Vol. II, pp. 48–78), Appendix G (NGSS Lead States, 2013, Vol. II, pp. 79–95)

Evaluation of Understanding and Application of Content Knowledge	Question	STANDARDS A:		STANDARDS B: *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	How do the standards expect students to proficiently demonstrate the ability to support scientific hypotheses with evidence and sound scientific reasoning?			Performance expectations require the application of a practice of science or engineering with a core disciplinary idea(s) (Vol. II, p. 48). Specifically, the practices of "analyzing and interpreting data" (Vol. II, pp. 56–57) and "obtaining, evaluating, and communicating information" (Vol. II, pp. 64–65) require students to gather evidence while the practices of "constructing explanations" and "engaging in argument from evidence" require students to use that evidence to support a hypothesis with data and sound scientific reasoning. These practices are paired with core ideas in all of the scientific disciplines and are expected of students in each grade level.	Appendix F (NGSS Lead States, 2013, Vol. II, pp. 48–78)

Evaluation of Understanding and Application of Content Knowledge	Question	**STANDARDS A:**		**STANDARDS B:** *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	How do the standards expect students to demonstrate an understanding of the origin and development of scientific content knowledge (i.e., "How do we know what we know?")?			The "Understandings About the Nature of Science" in the NGSS requires an understanding of the origin and development of scientific content knowledge. The themes within the nature of science are addressed by both the practices and crosscutting concepts, as seen in the performance expectations, and build in complexity across the grade levels (Vol. II, p. 97). Specifically, the themes of "science is a human endeavor" and "science as a way of knowing" are addressed by the crosscutting concepts, and the themes of "scientific investigations use a variety of methods," "scientific knowledge is based on empirical evidence," and "scientific knowledge is open to revision in light of new evidence" are included in the practices (Vol. II, pp. 98–99).	Appendix H (NGSS Lead States, 2013, Vol. II, pp. 96–102)

Evaluation of Understanding and Application of Content Knowledge	Question	**STANDARDS A:**		**STANDARDS B:** *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	In what ways do the standards require students to combine or synthesize multiple content ideas to demonstrate a deeper understanding of a large, broad theme within science or a specific scientific discipline?			The NGSS are composed of student performance expectations, which are statements of what students should know and be able to do at the end of each grade band (in middle and high school) and grade level (in elementary school) (Vol. I, p. xxiii). In the NGSS, performance expectations are grouped together based on how they support or build up to a core idea. In this way, a single performance expectation that requires the student to apply a science or engineering practice to one aspect of a core idea can be combined with the other performance expectations in the group to address multiple facets of the disciplinary core idea, leading to a greater depth of understanding of that core idea. For example, all of the components of the disciplinary core idea HS-ESS1: Earth's Place in the Universe listed in the disciplinary core idea foundation box are addressed in total by the six performance expectations HS-ESS1-1 to HS-ESS1-6 (Vol. I, pp. 119–121). By demonstrating proficiency in all the performance expectations of HS-ESS1, the student will have demonstrated a deeper understanding of the broader theme of the core idea. Each of the core ideas also builds in complexity from grade level to grade level, with increasingly more sophisticated performance expectations that address that core idea at each grade level band (Vol. II, pp. 41–47).	"How to Read the Next Generation Science Standards" (NGSS Lead States, 2013, Vol. I, pp. xxii–xxvi), Appendix E (NGSS Lead States, 2013, Vol. II, pp. 40–47)

Research on the Incorporation of Engineering Design and Methods into Science Standards

Modern society is increasingly reliant on engineering and technology to increase connectivity, communication and worker productivity and to confront and address modern challenges, including those related to the environment, resources availability and natural hazards (AAAS, 1989, pp. 25–37, 107–126; AAAS, 1993, pp. 181–191; NAE and NRC, 2002, pp. 25–44; NRC, 2009a, pp. 36–37). Students who learn engineering skills and habits of mind related to the nature of technology, technology and society, and the engineering design process will be prepared for successful employment, postsecondary education, and democratic citizenship in an increasingly technology-dependent world (Dugger and Gilberti, 2000, pp. 2–10; NRC, 2009a, pp. 44–45). Given the increasing demand for technological and engineering skills in the workplace, it is important that all students, regardless of race, gender or social status, have the opportunity to build those skills and knowledge (Cantrell et al., 2006; NAE and NRC, 2002; NRC, 2009a, p. 44; NRC, 2012b, p. 31).

Engineering habits of mind include systems thinking, creativity, optimism, collaboration, communication and attention to ethical considerations (NRC, 2009a, p. 5), while engineering methods through the design process involve solving problems in a highly iterative manner through the identification of the problem, the development of possible solutions, testing of those solutions and then the evaluation of the test results to optimize existing designs, to develop new solutions, or to better identify the problem (Dym et al., 2005; Fortus et al., 2004; Kolodner et al., 2003; NRC, 2009a, pp. 38–39). Engineering methods are applied with the knowledge that one problem may have more than one solution, that failure is an essential part of the process and that there are trade-offs (e.g., budget constraints or societal considerations) that must be considered when developing and optimizing solutions (AAAS, 1989, pp. 28–37; Kolodner et al., 1998). Because concepts covered repetitively over time lead to a greater depth of understanding, engineering-related standards that address the design process could include increasingly more complex problems that require a greater number of solutions and have more trade-offs to consider (NRC, 2012a, pp. 201–214). Students can demonstrate understanding by participating in the design process in a standalone course, by applying engineering principles and habits of mind in mathematical and scientific contexts (e.g., engineering as a pedagogical strategy for science and mathematics), through integration with science and math standards, or by considering engineering in the context of the nature and history of technology (e.g., cultural, social, economic and political dimensions of technology development and technological literacy).

There is evidence that, when integrated with science content, incorporation of engineering in science standards can lead to an overall increase in understanding of science (Cantrell et al., 2006; Fortus et al., 2005). Application of engineering practices to scientific contexts improves understanding and encourages greater depth of understanding of science content by (a) providing different, novel contexts for science learning; (b) providing real world context to better learn more abstract scientific concepts; (c) encouraging discussion of scientific concepts as solutions are being formulated; and (d) encouraging students to reexamine their understanding of science concepts as they test and optimize design solutions (Fortus et al., 2005). Understanding of engineering processes is enhanced by applying engineering design methodologies to scientific questions because science questions provide culturally relevant contexts that students can better identify with and because they provide realistic constraints to consider when identifying the trade-offs in the design process (NRC, 2009a, pp. 43–44). Overall, the study of scientific inquiry with engineering design enhances the understanding of each because it emphasizes the similarities in habits of mind and processes (e.g., systems thinking, creativity, collaboration, communication, reasoning to solve problems, brainstorming, using analogy and models, evidence-based evaluation, and prediction) and accentuates the differences between the approaches and goals of each (AAAS, 1989, pp. 26–27; Fortus et al., 2004; Kolodner et al., 2003; NRC, 2009a, pp. 41–43).

Incorporation of Engineering Design and Methods into Science Standards	Question	**<u>STANDARDS A:</u>**		**<u>STANDARDS B:</u>** *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	How do the standards define engineering skills and habits of mind, and in what ways are students expected to demonstrate an understanding of these?			Engineering practices are raised to the level of traditional science practices and include behaviors that engineers engage in, such as "defining problems" and "designing solutions" (Vol. II, pp. 49, 104). There are eight engineering practices defined by the NGSS and the NRC Framework (2012a), most of which have equivalents in science: defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; designing solutions; engaging in argument from evidence; and obtaining, evaluating, and communicating information. These practices are incorporated throughout the NGSS with the disciplinary core ideas and crosscutting concepts in performance expectations; students are expected to demonstrate engineering design methods as applied to the content of the core ideas. The NGSS also expect students to develop an understanding of some core engineering design principles — the disciplinary core idea ETS1 is devoted to describing engineering as a discipline and serves as the foundation for engineering-specific performance expectations from kindergarten through 12th grade.	Appendix F (NGSS Lead States, 2013, Vol. II, pp. 48–78), Appendix I (NGSS Lead States, 2013, Vol. II, pp. 103–107)

	Question	STANDARDS A:		STANDARDS B: *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
Incorporation of Engineering Design and Methods into Science Standards	How are students expected to demonstrate increasing levels of proficiency over time in the use of engineering design methods, including the use of redesign in the engineering design process?			The NGSS include the core idea of engineering design that requires use of engineering methods and practices that build coherently and grow in complexity and sophistication from grade level to grade level (Vol. II, pp. 49–67, 104–107). Of the three components of this core idea, "optimizing the design solution" requires students to test their designs and to refine the final design in the process of optimization (Vol. II, p. 104; e.g., HS-ETS1, Vol. I, pp. 129–130).	Appendix F (NGSS Lead States, 2013, Vol. II, pp. 48–78), Appendix I (NGSS Lead States, 2013, Vol. II, pp. 103–107)
	For which students are the engineering-related standards a requirement (e.g. graduation requirement)?			Engineering design is integrated throughout the standards and is required of every student in two ways: (1) with science specific performance expectations that apply engineering practices and (2) with engineering-specific performance expectations that focus on engineering design at the K–2, 3–5, 6–8 and 9–12 grade-level bands (Vol. II, pp. 104–107).	Appendix I (NGSS Lead States, 2013, Vol. II, pp. 103–107)

Incorporation of Engineering Design and Methods into Science Standards	Question	**STANDARDS A:**		**STANDARDS B:** *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	How and to what degree are engineering methods and the design process coupled with the science content standards to enhance the learning of both?			Engineering method and design, as both practice and disciplinary content, are coupled with science content in each grade band of the NGSS (Vol. II, p. 104).	Appendix I (NGSS Lead States, 2013, Vol. II, pp. 103–107)

Research on Course Sequencing and Relationships with Courses in Other Content Areas

A feature of the science education requirements of high-performing countries is that they have a core set of standards that involve application of content using mathematics, literacy and language arts skills while being open for advanced coursework for students to excel beyond the core standards (Linn, 2000; NCES, 1992, pp. 29–38; NGA-CCSSO-Achieve, 2008; NRC, 2007, p. 216; Schmidt et al., 2005; Valverde and Schmidt, 2000). Such standards apply to all students as a requirement for graduation (AAAS, 1989, p. xviii; Linn, 2000; NRC, 2012a, pp. 277–278). To enhance the success of all students with such standards and to be sure that the standards can be covered within a typical school year, fewer concepts are covered but they are explored in greater depth (Schmidt et al., 2005; Valverde and Schmidt, 2000)

Although all students should meet the expectations of a core set of achievable science standards, these would not limit further study by advanced students beyond the minimum set by the standards (Linn, 2000; NRC, 2002b, p. 12; NRC, 2012a, pp. 277–278). Opportunities for students to accelerate beyond the core requirements of K–12 education in the United States are provided by the availability of advanced coursework, such as upper-level science courses, Advanced Placement (AP) classes or through partnerships with universities (NRC, 2002b, pp. 103–116). Advanced coursework allows students to build on a foundation of content knowledge as well as skills of inquiry, analysis, and problem solving. For a student to be successful, the standards that lead up to this advanced coursework must account for the development of these skills and of a deep understanding of the core concepts of content knowledge (NRC, 2002b, pp. 23, 36–47).

Science standards that support students' advanced study often include language arts and mathematics concepts and skills. Standards that include the nature of science, application of content and application of science skills (e.g., inquiry or science and engineering methodologies) could require students to apply reading, writing, and speaking and listening skills through activities such as the critical analysis of evidence or sources, evidence-based argumentation and explanation, and communicating scientific findings in multiple forms (AAAS, 1989, pp. 1–12; Minner et al., 2010; NRC, 2002a, pp. 18–20; Zimmerman, 2007). Similarly, standards that include computation, data collection and analysis, math-based explanations of science concepts, and the presentation of data using graphs as essential components of science learning will include a demonstration of skill in using numbers and quantities, functions, mathematical models, principles of geometry, measurement, graphing, and statistics and probability. In this way, science standards can enhance learning in other areas by providing context for learning transfer (Rebello et al., 1998).

Course Sequencing and Relationships with Courses in Other Content Areas	Question	**STANDARDS A:**		**STANDARDS B:** *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	In what ways do the standards provide a foundation for AP courses or other advanced coursework?			The NGSS performance expectations are specifically designed not to limit the curriculum and to allow students interested in continuing their coursework in science or engineering the opportunity to do so (Vol. II, pp. 113–115). The NGSS performance expectations provide a foundation for rigorous advanced courses in science or engineering. During the NGSS development process, more than a hundred university and community college professors, as well as career training program instructors, met together to examine the NGSS expectations to ensure that they would provide a thorough foundation for entry-level courses in their fields. Course models are currently being developed to show how the NGSS standards could specifically lead into advanced study in AP courses.	Appendix K (NGSS Lead States, 2013, Vol. II, pp. 113–136), pending AP course models

	Question	STANDARDS A:		STANDARDS B: *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	Evidence from Standards A	How Do Standards B Address the Question?	Evidence from Standards B
Course Sequencing and Relationships with Courses in Other Content Areas	How and to what extent do the science standards require the application of knowledge from other content areas as well as enhance learning in these other areas, including English language arts and mathematics?			The NGSS were designed to align and keep pace with the Common Core State Standards (CCSS) in math and English language arts (ELA), and the performance expectations are explicitly connected to the specific CCSS standards (Vol. I, p. xxvi; Vol. II, pp. 50, 137, 158). These connections highlight how the performance expectations require mathematic principles to more deeply understand the core ideas as well as the role of writing, reasoning, and communication in understanding and applying the core ideas via the practices (Vol. II, pp. 27–28, 50, 137–138, 158). In addition, these connections also provide suggestions for where science skills and knowledge could be built simultaneously with mathematics or ELA skills and knowledge.	Appendix L (NGSS Lead States, 2013, Vol. II, pp. 137–157), Appendix M (NGSS Lead States, 2013, Vol. II, pp. 158–169)

Research on Preparing Students for College, Career and Citizenship

Employers report that they are looking for employees with a broad knowledge base, including a solid foundation of content knowledge in the sciences. They desire employees to be adaptive, optimistic, innovative, self-managed critical thinkers who can make judgments based on evidence, solve complex problems, process information from a variety of sources (written, oral and technical/mathematical) and communicate (oral and written) clearly (AACU, 2013; Coles, 1998; NRC, 2010, pp. 9–15). Standards that integrate content knowledge with the methods and habits of mind of science and engineering, such as through incorporating the nature of science into the standards, prepare students for an increasingly changeable job market. These methods and habits of mind include conducting research-style, inquiry-based projects; thinking in terms of systems; using evidence-based analysis in the context of science and engineering content; practicing problem solving in respect to scientific or engineering problems; building interpersonal and communication skills by working in teams to test designs, making observations, gathering data, and communicating findings; and generally applying content knowledge in real-world settings (NRC, 2002a, pp. 18–20; NRC, 2009a, pp. 38–39; NRC, 2010, pp. 19–25; NRC, 2012b, pp. 136–139). These same skills are also expected of students entering college or technical programs, so that standards incorporating methods and habits of mind of science and engineering are preparing all students for the future whether they are entering college, technical training, or the workforce following graduation (Carnevale et al., 2012; Conley, 2010, pp. 4–6, 19–52; Griffiths and Cahill, 2009; Lazzaro, 2010; NRC, 2009a, pp. 44–45; Tai et al., 2005).

Science standards that include aspects of the nature of science and engineering also provide students with a deeper understanding of how science is practiced in society, how decisions and discoveries in science and engineering impact society, and what the scientific enterprise can and cannot do to address societal needs and concerns (NRC, 1996, pp. 19–24). By participating in processes of questioning, investigation, using terminology, data collection and analysis, and argumentation based on evidence, students can better appreciate that "the World Is Understandable" and that "Scientific Knowledge Is Durable," but also that "Scientific Ideas Are Subject To Change" and that "Science Cannot Provide Complete Answers to All Questions" (AAAS, 1989, pp. 1–12; McComas et al., 1998). Also, by learning about how science is currently done in society, they can appreciate that science is a human endeavor where many different people from different disciplines and institutions work together to ethically study natural processes as specialists while participating in the world as citizens (NRC, 2007, pp. 168–179). Without an appreciation for the nature of science, scientific factual knowledge may be misinterpreted or misunderstood when used by policymakers, members of the justice system, and the public (NRC, 2012b, pp. 59–61). For this reason, a deeper understanding of the nature of science and engineering, as well as science and engineering habits of mind and methods, are essential for all students and not just those for whom science may become a profession.

To build knowledgeable future decision makers and citizens, and to prepare all students for a technical and intellectually demanding job market, it is important to have opportunities to apply science and engineering methods available to all groups, especially minorities and females (AAAS, 1989, p. xviii; Lee and Buxton, 2010; NRC, 1996, p. 20). Success of a diverse range of students can be facilitated by having those students learn and apply science and engineering methods in contexts familiar to them (e.g., specific to their cultural background), by providing multiple opportunities for learning, and by providing more than one way to engage the content so that all different types of learners can succeed, including students with learning disabilities and English language learners (NRC, 2002a, pp. 116–120; NRC, 2002b, pp. 117–129; NRC, 2008, pp. 97–103; NRC, 2009b, pp. 209–232 ; NRC, 2012a, pp. 277–299; Zimmerman, 2007).

Preparing Students for College, Career and Citizenship	Question	STANDARDS A:		STANDARDS B: *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	In what ways do the standards help students develop the technical knowledge requirements and the collaboration, communication, and problem-solving skills desired by employers (e.g., in preparation for career and technical education programs or direct employment out of high school)?			The NGSS integrate science and engineering practices throughout the K–12 standards and describe explicit connections to the CCSS in math and ELA — thereby expecting students to develop habits, skills and knowledge specifically applicable to many technical fields or preparation programs (Vol. II, pp. 11–14, 17–20, 25–30, 138). To be proficient in the NGSS, students will need to develop the means to communicate effectively and the critical-thinking and problem-solving skills necessary for employment in a rapidly changing job market.	Appendix C (NGSS Lead States, 2013, Vol. II, pp. 11–24), Appendix D (NGSS Lead States, 2013, Vol. II, pp. 25–39)

Preparing Students for College, Career and Citizenship	Question	STANDARDS A:		STANDARDS B: *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	Evidence from Standards A	How Do Standards B Address the Question?	Evidence from Standards B
	How do the standards reflect the ways in which science and engineering are currently practiced in society as well as how these disciplines impact society and address societal needs and concerns?			By integrating science and engineering practices with core ideas and by describing connections to the CCSS in math and ELA, the NGSS better reflect the interconnection of science, engineering and math in industry (Vol. II, pp. 17–20, 49–50, 103–104, 138). The inclusion of engineering and science practices reflects the emphasis on investigation and innovation in technical fields. The NRC Framework (2012a) disciplinary core idea of ETS2, "Links among engineering, technology, science, and society," is included in the NGSS as an overarching, cross-disciplinary idea, and the specific components of this idea are explicitly stated within the foundation boxes where they apply to individual performance expectations in each of the scientific disciplines and across grade bands (e.g., HS-ESS1, Vol. I, p. 120). The standards that specifically address the interrelationship among science, engineering and human society help students develop the understanding that technological advances can have a profound impact on society and the environment (Vol. II, pp. 108–111, including the "Science, Technology, Society, and the Environment Connections Matrix"). This highlights the importance of technology in developing scientific understanding and the importance of science in driving technological innovation.	Appendix C (NGSS Lead States, 2013, Vol. II, pp. 11–24), Appendix J (NGSS Lead States, 2013, Vol. II, pp. 108–112)

Preparing Students for College, Career and Citizenship	Question	**STANDARDS A:**		**STANDARDS B:** *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	**Evidence from Standards A**	**How Do Standards B Address the Question?**	**Evidence from Standards B**
	To what extent do the science standards explicitly support underserved student populations and those populations that traditionally have not succeeded in science and engineering (e.g., females, minorities, English language learners, etc.)?			The NGSS describe performance expectations for all students, raising the expectations for students who might not otherwise take much science in high school. The NGSS also make connections across the school curricula, including to mathematics and ELA. In addition, the NGSS practices converge with the math and ELA practices. These connections are beneficial for students from non-dominant groups who are pressed during instructional time to develop literacy and numeracy skills at the cost of others, including science. The NGSS integrate science and engineering practices in every performance expectation, providing students an opportunity to demonstrate their understanding in multiple, diverse ways and providing a justification for multiple, diverse modes of instruction. By emphasizing engineering, the NGSS recognize the contributions of non-dominant cultures and groups to science and engineering. Engineering also has the potential to be inclusive of students who have traditionally been marginalized in the science classroom and who do not see science as being relevant to their lives or future (Vol. II, pp. 27–30). By solving problems through engineering in local contexts, students view science as *(answer is continued on next page)*	Appendix D (NGSS Lead States, 2013, Vol. II, pp.25–39), www.nextgenscience.org/appendix-d-case-studies

	Question	STANDARDS A:		STANDARDS B: *Next Generation Science Standards (2013)*	
		How Do Standards A Address the Question?	Evidence from Standards A	How Do Standards B Address the Question?	Evidence from Standards B
				(*answer starts on preceding page*) relevant to their lives and future and engage in science in socially relevant and transformative ways. Engagement in any of the scientific and engineering practices involves both critical thinking and communication skills (Vol. II, p. 50). Because the NGSS are required of all students, these skills will help English language learners to practice language skills. Finally, the integration of practices with crosscutting concepts requires students to think deeply about material and to make connections among big ideas that cut across disciplines, which provides opportunities for learning that have not traditionally been available to disadvantaged or less-privileged learners (Vol. II, pp. 80–81). The following case studies are provided to detail how the NGSS can be used to benefit diverse groups of students: (1) Economically Disadvantaged, (2) Race and Ethnicity, (3) Students with Disabilities, (4) English Language Learners, (5) Girls, (6) Alternative Education, (7) Gifted and Talented Students (www.nextgenscience.org/appendix-d-case-studies).	

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