A Comparison Between the Next Generation Science Standards (NGSS) and the National Assessment of Educational Progress (NAEP) Frameworks in Science, Technology and Engineering Literacy, and Mathematics

An Executive Summary

September 2015

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September 2015

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The study *A Comparison Between the Next Generation Science Standards (NGSS) and the National Assessment of Educational Progress (NAEP) Frameworks in Science, Technology and Engineering Literacy, and Mathematics* was conducted for NCES under Contract No. ED-IES-12-D-0002/0004 with American Institutes for Research**.** Mention of trade names, commercial products, or organizations does not imply endorsement by the U.S. Government.

Three reports—an Executive Summary, a Highlights Report, and a Technical Report—document the findings from the study and can be found at http://nces.ed.gov/nationsreportcard/science.

Suggested Citation
Neidorf, T., Stephens, M., Lasseter, A., Gattis, K., Arora, A., Wang, Y., Guile, S., Holmes, J. (2015). *A Comparison Between the Next Generation Science Standards (NGSS) and the National Assessment of Educational Progress (NAEP) Frameworks in Science, Technology and Engineering Literacy, and Mathematics*. U.S. Department of Education. Washington, DC: National Center for Education Statistics. Retrieved [date] from http://nces.ed.gov/nationsreportcard/science.

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Comparing the NGSS with the NAEP STEM Frameworks: An Executive Summary

New national standards documents have been developed during the past few years in science, technology, engineering, and mathematics (STEM) and are leading to major changes in state curricula and assessments. Knowing how these standards are related to the existing national frameworks for assessing student achievement in STEM areas that are provided by the National Assessment of Educational Progress (NAEP) is important for policymakers, researchers, educators, and the public.

What standards and frameworks were compared?

The most recently developed national STEM standards are the **Next Generation Science Standards (NGSS)**.[1] The NGSS elaborate a set of concrete student outcomes (performance expectations) for science and engineering across grades K–12. These performance expectations describe what *all* students should know and be able to do at each grade level in order to demonstrate that they have met the standards. Thus, the NGSS inform curriculum development, instruction, professional development, and student assessment. The NGSS are based on three dimensions: (1) disciplinary core ideas within four content domains that include the three natural sciences (physical, life, and Earth and space sciences) and engineering, technology, and applications of science; (2) scientific and engineering practices that elaborate the processes and habits of mind in science and engineering that should be developed and applied (including some mathematics-related practices); and (3) crosscutting concepts that unify the study of science and engineering. For more details on the content domains and practices, see figure 1. The NGSS describe a set of performance expectations at various grades or grade bands that integrate specific content (core ideas in the content domains) with specific practices but do not specify how the performance expectations should be assessed or distributed in grade-based assessments. For example, a grade 4 performance expectation in physical sciences expects students to "use evidence to construct an explanation relating the speed of an object to the energy of that object" and one in engineering design expects students to "generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem." To access the full set of NGSS performance expectations, use the NGSS link in footnote 1.

In comparison, the three **NAEP STEM frameworks—science, technology and engineering literacy (TEL), and mathematics—**are explicitly intended to guide the development of assessments at grades 4, 8, and 12 that cover a range of knowledge and skills; they describe in detail the content and cognitive dimensions to be assessed and how the assessments should be distributed across the categories within these dimensions.[2] There are three content areas in science and three assessment areas in TEL, while the cognitive dimensions describe four broad science practices and three TEL practices that articulate the types of thinking, reasoning, and application required of students (see figure 1). The mathematics framework includes five content areas and a cognitive dimension that defines three levels of mathematical complexity. All three NAEP STEM frameworks define a set of grade-specific content objectives, which are the NAEP framework components most analogous to the NGSS performance expectations. For science and TEL, the content objectives can be combined with different practices to produce a broad range of possible assessment tasks at each grade. For example, the NAEP science framework includes a grade 4 objective in physical science that expects students to demonstrate and apply knowledge that "one way to change matter from one state to another and back again is by heating and cooling." The NAEP TEL framework includes a grade 4

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[1] The NGSS were prepared by the NGSS Lead States (coordinated by Achieve) and published in 2013 by the National Academies Press. They are based on the National Research Council's *A Framework for K–12 Science Education*, published in 2012. They have been followed up with the National Research Council's *Developing Assessments for the Next Generation Science Standards* in 2014 and *Guide to Implementing the Next Generation Science Standards* in 2015.
[2] The NAEP frameworks are published by the National Assessment Governing Board. The most recent science and mathematics frameworks were published in 2014 and the TEL framework was published in 2013.

objective expecting students to "use a systematic process to design a solution to a simple problem." To access the full set of NAEP content objectives (which are referred to as content statements in science and assessment targets in TEL), use the NAEP framework links in footnote 2.

Exhibit 1. Content and practices dimensions of the NGSS and the NAEP science and TEL frameworks

NGSS[1]	NAEP Science Framework	NAEP TEL Framework
Content domains 1. Physical sciences 2. Life sciences 3. Earth and space sciences 4. Engineering, technology, and applications of science (ETS)[2]	**Content areas** 1. Physical science 2. Life science 3. Earth and space sciences	**Assessment areas** 1. Design and systems 2. Technology and society 3. Information and communication technology
Scientific and engineering practices 1. Asking questions and defining problems 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing explanations and designing solutions 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information	**Science practices** 1. Identifying science principles 2. Using science principles 3. Using scientific inquiry 4. Using technological design	**TEL practices** 1. Understanding technological principles 2. Developing solutions and achieving goals 3. Communicating and collaborating

[1] This figure does not show NGSS's third dimension, crosscutting concepts, which apply across the content domains and are reflected in the content of the performance expectations. There is no analogous separate dimension in NAEP.

[2] The ETS content domain includes engineering design and links among engineering, technology, science, and society.

What was the goal of the study?

The main goal of the study was to determine the extent to which the NGSS performance expectations are aligned with the content objectives and definitions of the practices in the NAEP science and TEL frameworks. An additional goal, which supplements the science and TEL comparisons, was to determine the extent to which NGSS performance expectations involving mathematics-related practices are aligned with the objectives in the NAEP mathematics framework.

How was the study conducted?

The study compared the relevant aspects of the NGSS with the appropriate NAEP framework at the corresponding grades. The most complete and parallel comparison was with the NAEP science framework, where NGSS performance expectations in the three content domains in the sciences (physical, life, and Earth and space sciences) were compared with the NAEP objectives in the analogous content areas. In these comparisons, NGSS performance expectations in the sciences at grade 4, middle school, and high school were compared with NAEP science objectives at grades 4, 8, and 12; additionally, some performance expectations at grades 3 and 5 were compared. The NGSS performance expectations in the fourth content domain— engineering, technology, and applications of science (ETS)—were compared with objectives in the NAEP TEL framework at grades 4, 8, and 12. Two types of ETS performance expectations were included in the TEL comparisons: those in engineering design in the 3–5 (upper elementary), middle school, and high school grade bands; and those in the sciences with explicit connections to ETS at grade 4, middle school, and high school. For mathematics, the NGSS performance expectations in both the sciences and engineering design that involve mathematics-related practices were compared with NAEP mathematics objectives at grades 4, 8, and 12.

The study, commissioned by the National Center for Education Statistics, was undertaken by researchers from American Institutes for Research, who were responsible for its implementation and analysis, and subject-specific panels of experts, who provided the ratings of alignment described below.

To what degree are the NGSS covered by NAEP science and TEL?

The main findings from the study focus on the extent to which the content and practices reflected in the NGSS performance expectations are covered by the content and practices in the NAEP science and TEL frameworks. Specifically, the study examined (1) content overlap, (2) content alignment, and (3) practices alignment (each defined below).

Content overlap

Content overlap refers to NGSS performance expectations in the four content domains (shown in figure 1) that were judged as covering related content to NAEP science or TEL objectives at the corresponding grade level. Overlapping objectives were next rated by experts to determine the degree of content alignment (described below). Content overlap, therefore, indicates the *potential* for content alignment between the NGSS and the NAEP science and TEL frameworks at specific grade levels. The results suggest a moderate to substantial degree of content overlap.

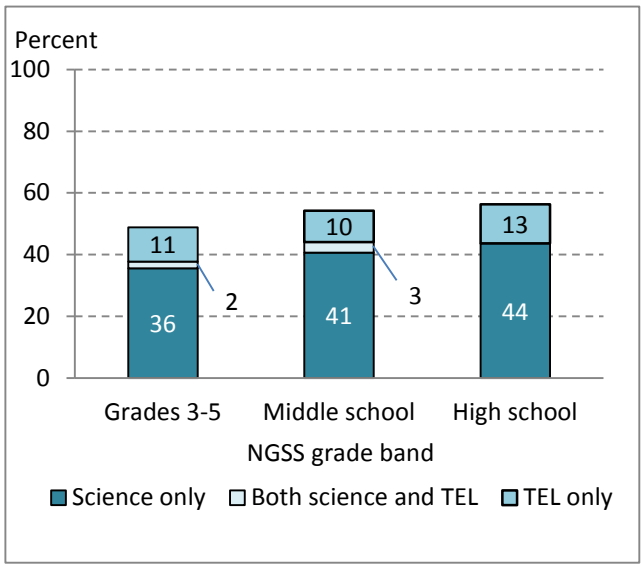
- Fifty-six percent of the NGSS performance expectations across the four content domains at the upper elementary level (grades 3–5) covered content that overlaps with NAEP science or TEL at grade 4. Ninety percent or more of NGSS performance expectations at the middle school and high school levels covered content that overlaps with NAEP science or TEL at grades 8 and 12, respectively.

Content alignment

Content alignment refers to overlapping NGSS performance expectations and NAEP objectives that experts rated as "similar." Content alignment indicates that the overlapping objectives in the NGSS and NAEP science and TEL frameworks are similar enough in depth, breadth, detail, and focus that they could lead to similar assessment tasks at the corresponding grade level. Content alignment differed by grade and content domain and was lower than content overlap.

- Roughly half of the NGSS performance expectations in the sciences and engineering design were aligned to the NAEP science or TEL framework, or both, at the corresponding grade (see figure 2). At grades 3–5, 38 percent of performance expectations were aligned to the science framework and 13 percent to the TEL framework, with 2 percent in the sciences aligned to both. At the middle school level, 44 percent of performance expectations were aligned to the science framework and 13 percent to the TEL framework, with 3 percent in the sciences aligned to both. At the high school level, 44 percent of performance expectations were aligned to the science framework and 13 percent to the TEL framework.

Figure 1. Percentage of NGSS performance expectations aligned to the NAEP science and TEL frameworks, by framework and grade band



NOTE: For additional information, see the Highlights Report and Technical Report available at http://nces.ed.gov/nationsreportcard/science.

- In the sciences, considering only the grade 4 NGSS performance expectations, 36 percent were aligned to the NAEP science framework at grade 4. About one-half of performance expectations in the sciences at the middle school (47 percent) and high school (46 percent) levels were aligned to the NAEP science framework at grades 8 and 12, respectively. Overall, about 9 percent of NGSS performance expectations were aligned to a lower or higher grade level in NAEP science.
- Across grades, the greatest degree of alignment to the NAEP science framework was in life sciences (ranging from 48 to 54 percent of NGSS performance expectations aligned to NAEP). In contrast, the lowest degree of alignment was in physical sciences (ranging from 29 to 42 percent of NGSS performance expectations aligned to NAEP).
- In engineering, technology, and applications of science, 86 percent of NGSS performance expectations in grades 3–5—including both those in engineering design and in the sciences with connections to ETS—were aligned to the NAEP TEL framework, in comparison with 53 percent at the middle school and 45 percent at the high school levels. Rates of alignment were higher for performance expectations in engineering design (from 75 to 100 percent) than for those in the sciences with connections to ETS (from 38 to 75 percent).

Practices alignment

Practices alignment refers to NGSS performance expectations whose associated scientific and engineering practices were aligned to a NAEP science or TEL practice (shown in figure 1). Practices alignment identifies the primary NAEP science or TEL practices that were aligned to the NGSS performance expectations.

- Ninety-nine percent of NGSS performance expectations in the natural sciences were aligned to NAEP science practices and 81 percent of performance expectations in engineering, technology, and applications of science were aligned to NAEP TEL practices.
- The distribution of NGSS performance expectations across NAEP science and TEL practices, however, differed from the emphasis across practices specified in the NAEP frameworks. Notably, NGSS performance expectations in the natural sciences have a greater emphasis (60 percent) on the NAEP practice of *using science principles* (focused on applying knowledge of science principles to predict, explain, and reason from models) and a great deal less emphasis (4 percent) on *identifying science principles* (focused on the ability to recall, define, relate, and represent science principles) than the NAEP science framework. The emphasis on *using scientific inquiry* (22 percent) and *using technological design* (13 percent) is more comparable to NAEP science. NGSS performance expectations in ETS are concentrated (62 percent) in the NAEP TEL practice of *designing solutions and achieving goals* (focused on the systematic application of technological knowledge, tools, and skills to address problems and achieve goals), with little emphasis on *understanding technological principles* (12 percent) and *communicating and collaborating* (7 percent).

Do the mathematics-related practices in the NGSS align with the NAEP mathematics framework?

Alignment in mathematics refers to NGSS performance expectations whose associated practices involve mathematics that is included in NAEP mathematics objectives at the corresponding grade level or in two adjacent grade levels in the NAEP framework (i.e., grades 4 and 8 or grades 8 and 12). Alignment in mathematics indicates the extent to which the mathematics that may be involved in science and engineering assessment tasks that are developed based on the NGSS is included in the NAEP framework and at what grade level(s).

- All of the mathematics-related performance expectations at grade 4 and at least 87 percent at the middle and high school levels aligned to objectives in the NAEP framework. However, 92 percent of the performance expectations at grade 4 involved some mathematics that was more consistent with NAEP objectives at grade 8 and were aligned at both grade 4 and grade 8; 27 percent of those at the middle school level involved some mathematics that was more consistent with NAEP objectives at grade 12 and were aligned at both grade 8 and grade 12.

Conclusions

The NGSS showed moderate to substantial *content overlap* with the NAEP science and TEL frameworks, but differences in the depth, breadth, detail, or focus of that content resulted in low to moderate levels of *content alignment*, with differences by grade and content domain. *Practices alignment* was strong, but the emphasis of NGSS performance expectations across NAEP science and TEL practices differed from the emphases specified in the NAEP frameworks.

These results suggest that assessments based on the NGSS and the NAEP science and TEL assessments would be aligned to some degree, but each would also have unique content and different emphases in terms of science and TEL practices. Alignment of an NGSS-based assessment with the NAEP science assessment would likely be low at grade 4 and moderate at the middle school and high school levels. In addition, tasks developed to assess the NGSS performance expectations may require students to use some mathematics that is beyond the corresponding grade level in the NAEP mathematics framework; this is in contrast to the NAEP science and TEL assessments, which require mathematics at or below the corresponding grade level.