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

Highlights Report

November 2015

Teresa Neidorf
Maria Stephens
Austin Lasseter
Kim Gattis
Alka Arora
Yan Wang
Sarah Guile
Juliet Holmes
American Institutes for Research

Taslima Rahman
Project Officer
National Center for Education Statistics

U.S. Department of Education
Arne Duncan
Secretary

Institute of Education Sciences
Ruth Neild
Acting Director

National Center for Education Statistics
Peggy Carr
Acting Commissioner

The National Center for Education Statistics (NCES) is the primary federal entity for collecting, analyzing, and reporting data related to education in the United States and other nations. It fulfills a congressional mandate to collect, collate, analyze, and report full and complete statistics on the condition of education in the United States; conduct and publish reports and specialized analyses of the meaning and significance of such statistics; assist state and local education agencies in improving their statistical systems; and review and report on education activities in foreign countries.

NCES activities are designed to address high-priority education data needs; provide consistent, reliable, complete, and accurate indicators of education status and trends; and report timely, useful, and high-quality data to the U.S. Department of Education, the Congress, the states, other education policymakers, practitioners, data users, and the general public. Unless specifically noted, all information contained herein is in the public domain.

NCES, IES, U.S. Department of Education
1990 K Street NW
Washington, DC 20006-5651

September 2015

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.

Content Contact
Taslima Rahman
(202) 502-7316
Taslima.Rahman@ed.gov

Contents

Introduction

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. The most recent of these is the *Next Generation Science Standards* (NGSS Lead States 2013).[1] This document includes standards in the natural sciences, as well as in engineering, technology, and applications of science, and it emphasizes the fundamental role of mathematics in science and engineering. Knowing how such 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.

The National Center for Education Statistics thus commissioned a study to compare the NGSS with the three most closely related NAEP assessment frameworks: science, technology and engineering literacy (TEL) and, to a lesser extent, mathematics (NAGB 2013, NAGB 2014a, NAGB 20014b). The results of this study, which are highlighted in this report, can inform ongoing discussions of the content and design of NAEP assessments and the role of NAEP in emerging national systems of assessments in STEM subjects. The study may also be useful to states as they move forward with implementing the NGSS and for understanding differences between results from NAEP and NGSS-based assessments.

Overview of the NGSS and NAEP STEM frameworks

NGSS

The NGSS are based on the vision for science education first described in the National Research Council's *A Framework for K–12 Science Education* (NRC 2012).[2] 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, together with the K-12 framework, the NGSS inform curriculum development, instruction, professional development, and student assessment.

The NGSS and the K–12 Framework are based on three dimensions: disciplinary core ideas (within four content domains), scientific and engineering practices, and crosscutting concepts (see exhibit 1). The four content domains into which the disciplinary core ideas are organized are physical sciences; life sciences; Earth and space sciences; and engineering, technology, and applications of science (ETS). Eight scientific and engineering practices elaborate the processes and habits of mind in science and engineering that students should develop and apply (including some mathematics-related practices). The crosscutting concepts bridge the disciplines of science and engineering and emphasize fundamental connections that students should understand to have a coherent and scientifically based view of the world.

The NGSS describe performance expectations in the three natural science domains for each grade in elementary school (K–5), as well as for middle school (6–8) and high school (9–12) grade bands.

---

[1] The first set of state STEM standards was the *Common Core State Standards in Mathematics* (CCSS-M), which were developed by a state consortium and published in 2010.

[2] This is referred to throughout the report as the K–12 Framework.

Performance expectations in engineering are described by grade band: lower elementary (K–2), upper elementary (3–5), middle school (6–8), and high school (9–12).

A key feature of the performance expectations is that they *integrate* content and practices and reflect the crosscutting concepts. For example, one grade 4 NGSS 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." The integration of the three dimensions of the K–12 Framework is one of the strengths of the NGSS in terms of focusing on the most important outcomes at each grade level that all students should achieve. However, the specification of particular combinations of content and practices may restrict the range of tasks developed for specific grade-based assessments. The NGSS do not go as far, however, as to describe how the performance expectations should be assessed.[3]

NAEP STEM frameworks

In comparison, the NAEP frameworks in science, TEL, and mathematics are explicitly intended to guide the development of assessments at grades 4, 8, and 12. They describe in detail the content and cognitive dimensions to be assessed and identify the target percentage of the assessments that should be devoted to the main categories within each dimension at each grade level. They also describe the types and proportion of items and tasks to be included in the assessments.[4]

Like the NGSS, the NAEP science and TEL frameworks include a content dimension and a practices dimension (through which the cognitive demands are articulated and thus also referred to as the cognitive dimension) (see exhibit 1). However, the two dimensions are described separately in the NAEP frameworks rather than in an integrated fashion, as they are in the NGSS. This allows NAEP's content and practices to be combined in various ways to produce a broad range of performance expectations and resulting assessment tasks at any given grade. Such a range allows NAEP to meet its mission to assess student achievement across the full set of proficiency levels, from basic to advanced. This is distinct from the goal of the NGSS, which is to identify performance expectations that *all* students are expected to meet at each grade level.

[3] Creating assessment guidelines aligned with the NGSS is being undertaken by the states, with guidance from two documents recently published by the National Research Council (NRC): *Developing Assessments for the Next Generation Science Standards* (NRC 2014) and the *Guide to Implementing the Next Generation Science Standards* (NRC 2015).

[4] In general, NAEP includes both selected-response and constructed-response items, with at least half of each assessment devoted to the latter. Both the science and TEL assessments include scenario-based interactive computer tasks requiring students to apply their knowledge to conduct investigations and solve design problems. The NAEP science assessment also includes hands-on performance tasks requiring students to work with physical equipment and materials to conduct investigations.

Exhibit 1. Dimensions of the NGSS and the NAEP Science and TEL frameworks

NGSS	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)[1]	**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
Crosscutting concepts 1. Patterns 2. Cause and effect 3. Scale, proportion, and quantity 4. Systems and system models 5. Energy and matter: Flows, cycles, and conservation 6. Structure and function 7. Stability and change	[No analogous separate dimension][2]	[No analogous separate dimension]

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

[2] The NAEP science framework includes crosscutting content, but it is not treated as a separate dimension; rather, it is reflected in specific objectives in physical, life, and Earth and space sciences that cover key science principles across the content areas.

SOURCE: National Assessment Governing Board (NAGB). (2013). *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress*. Washington, DC; National Assessment Governing Board (NAGB). (2014a). *Mathematics Framework for the 2015 National Assessment of Educational Progress*. Washington, DC: U.S. Government Printing Office; National Assessment Governing Board (NAGB). (2014b). *Science Framework for the 2015 National Assessment of Educational Progress*. Washington, DC: U.S. Government Printing Office; and NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC. The National Academies.

The ***NAEP science framework*** content dimension is organized into three broad content areas—physical science, life science, and Earth and space sciences—which are further broken down into topics, then subtopics, and, finally, grade-specific content statements that describe the science principles that students should know. For example one grade 4 content statement in physical science 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 cognitive dimension includes four broad science practices that describe the ways in which students should use their knowledge of science principles: identifying science principles, using science principles, using scientific inquiry, and using technological design.

The ***NAEP TEL framework*** content dimension is organized into three assessment areas—design and systems, technology and society, and information and communication technology—each of which is further broken down into subareas, for which there are a set of grade-specific assessment targets that describe what students should either know or be able to do. For example one grade 4 assessment target in design and systems expects students to "use a systematic process to design a solution to a simple problem." The cognitive dimension includes three engineering and technology practices that articulate the types of thinking,

reasoning, and application required of students: understanding technological principles, designing solutions and achieving goals, and communicating and collaborating.

The ***NAEP mathematics framework*** content dimension is organized into five major content areas—number properties and operations; measurement; geometry; data analysis, statistics, and probability; and algebra—that are further divided into subtopics and grade-specific mathematics objectives. For example, a grade 4 objective expects students to "compare two sets of related data." The cognitive dimension differs from the practices in NAEP science and TEL frameworks, however, in that it defines three levels of mathematical complexity, or a hierarchical description of the mathematical demands placed on the student.

Exhibit 2 provides an overview of the NGSS and NAEP framework content dimension structure and the terminology used throughout the report. The grade-specific objectives in the NAEP frameworks (e.g., content statements in science, assessment targets in TEL, and objectives in mathematics) are the components most analogous to the NGSS performance expectations and thus they are the primary points of comparison in the study. This provides comparisons between the NGSS and the NAEP frameworks at the most detailed objective level.[5]

Exhibit 2. Overview of NGSS and NAEP framework content dimension structure and terminology

NGSS	***NAEP Science Framework***	***NAEP TEL Framework***	***NAEP Mathematics Framework***
Content domains (4)	Content areas (3)	Assessment areas (3)	Content areas (5)
↓	↓	↓	↓
Disciplinary core ideas	Topics	Subareas	Subtopics
↓	↓	↓	↓
Component ideas	Subtopics		
↓	↓		
Grade-specific (or level-specific) performance expectations	Grade-specific content statements	Grade-specific assessment targets	Grade-specific objectives

NOTE: Each document organizes the content dimension into different levels of specificity. Both the NGSS and the NAEP science framework have four levels, while the NAEP TEL and NAEP mathematics frameworks have only three. The levels shown do not necessarily indicate the same degree of specificity across frameworks, even when similar terms are used (e.g., "subtopics"); the way content is organized (and the terms used) is specific to the subject area and particular document. The last row of the exhibit indicates the grade-level content specifications for each document.

SOURCE: National Assessment Governing Board (NAGB). (2013). *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress*. Washington, DC; National Assessment Governing Board (NAGB). (2014a). *Mathematics Framework for the 2015 National Assessment of Educational Progress*. Washington, DC: U.S. Government Printing Office; National Assessment Governing Board (NAGB). (2014b). *Science Framework for the 2015 National Assessment of Educational Progress*. Washington, DC: U.S. Government Printing Office; and NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC. The National Academies.

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 framework and the NAEP TEL framework. An additional goal, which supplements the science and TEL comparisons, was to

[5] The term "objectives" is sometimes used generically in the report to refer to the grade-specific (or level-specific) performance expectations in the NGSS and the corresponding grade-level specifications in the NAEP framework documents (science content statements, TEL assessment targets, and mathematics objectives).

determine the extent to which NGSS performance expectations involving mathematics-related practices are aligned with the content objectives in the NAEP mathematics framework.

Benefits and limitations of the framework comparison study

There are multiple benefits in comparing the NGSS with the NAEP STEM frameworks. For the science framework comparisons, similarities suggest areas where NAEP may provide assessment measures and national achievement data on the student understandings in physical sciences, life sciences, and Earth and space sciences described in the NGSS. Differences suggest areas where NAEP and NGSS-based science assessments may each provide unique contributions. The TEL framework comparisons augment these findings by identifying additional areas of overlap with the engineering and technology content and practices in NGSS. Together, these comparisons explore how completely the full range of content and practices in the NGSS are covered by the NAEP science and TEL frameworks as well as the unique aspects of each.

The mathematics comparisons, while more limited, explore the degree of alignment between the mathematics-related performance expectations in the NGSS and the NAEP mathematics framework. The NGSS are not intended to guide mathematics assessments and do not include explicit requirements for the mathematics needed to demonstrate mastery of the science and engineering performance expectations. However, the mathematics that may be used by students in responding to items developed to assess these performance expectations can be inferred and compared with the mathematics included in NAEP across grades. Thus, comparisons between the NGSS and relevant aspects of the NAEP mathematics framework can supplement the science and TEL comparisons by providing information on how assessments based on the NGSS might compare with NAEP in terms of the level of mathematics and quantitative skills applied.

There are also some limitations to framework-level comparison studies to be considered. Framework comparisons are based on descriptions of the intended content and practices to be assessed. Evaluating the conceptual match between objectives in the frameworks, therefore, provides information on the potential alignment of content and practices that may be covered in assessments. However, the implementation of the frameworks in actual assessments may result in different emphases and scope. Results based on the proportion of framework objectives that are aligned may be used to project what is included in assessments, but this assumes a proportional representation of the objectives, which may or may not be the case. Future studies that compare the contents of actual assessments may be conducted that will build on the framework comparison results and provide more complete information on the alignment between the NGSS and NAEP science and TEL. Additionally, the level of mathematics may be explored in greater depth by examining the mathematics demands of actual assessment items and tasks from NAEP science and TEL and those based on the NGSS.

Research questions

Three research questions guided the framework comparison study:

1. *Related to the NAEP science framework*: How similar (or different) are the NGSS performance expectations in physical sciences, life sciences, and Earth and space sciences to the content and practices in the NAEP science framework at the corresponding grade levels?

2. *Related to the NAEP TEL framework*: How similar (or different) are the NGSS performance expectations in engineering, technology, and applications of science to the content and practices in the NAEP technology and engineering literacy framework at the corresponding grade levels?

3. *Related to the NAEP mathematics framework*: To what extent are the mathematics-related NGSS performance expectations and practices aligned with the content and skills specified in the NAEP mathematics framework, and at which grade(s)?

Study Design and Methodology

To answer these research questions, the study compared the relevant aspects of the NGSS with the appropriate NAEP STEM 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 natural sciences (physical sciences, life sciences, and Earth and space sciences) were compared with the NAEP content statements in the analogous content areas. NGSS performance expectations at grade 4, middle school, and high school were compared with NAEP science content statements at grades 4, 8, and 12, respectively. The NGSS performance expectations in the fourth content domain—engineering, technology, and applications of science (ETS)—were compared with NAEP TEL assessment targets at grades 4, 8, and 12. The TEL comparisons included two types of ETS performance expectations: those in engineering design in the grade 3–5, 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.[6]

Science and TEL comparisons

The general approach to the science and TEL comparisons was adapted from an approach developed by research staff at American Institutes for Research (AIR) and successfully used in prior framework comparison studies, including a recent comparison of the mathematics and science frameworks in NAEP and the Trends in International Mathematics and Science Study (TIMSS).[7] The comparisons of the NGSS with the NAEP science and TEL frameworks were conducted in three main steps:

[6] Mathematics-related performance expectations represented most of the performance expectations in the sciences and in engineering design.

[7] A comparison of the 2011 grade 8 NAEP and TIMSS mathematics and science frameworks (Gattis et al. 2013) was conducted by AIR to inform NCES's 2011 NAEP-TIMSS linking study: http://nces.ed.gov/nationsreportcard/studies/naep_timss/.

1. **Content mapping**. The AIR research team first prepared content-mapping documents that grouped the relevant portions of the NGSS performance expectations with NAEP framework objectives that covered related content at the corresponding grade level. The documents also identified non-grouped objectives from each framework that covered content that was unique to one framework at a given grade. The research team determined the content comparison groupings on the basis of their knowledge of and expertise with the NAEP science and TEL frameworks and assessments and their comprehensive reviews of the NGSS. These groupings served as the basis for the next step.

2. **Expert panel review and rating**. AIR next convened an external expert panel experienced with the NGSS and NAEP frameworks[8] to review the grouped and non-grouped objectives and to provide two main types of ratings: content similarity and practices alignment. The expert panel rated the *content similarity* on a scale of 1 to 4 (from "substantially or wholly different" to "exactly or almost the same") at three levels of framework specificity: (1) objectives (i.e., for each grouping), (2) content areas, and (3) overall framework. For the science comparisons, the panel also identified alternative groupings of objectives at other grade levels that were aligned for content. The expert panel determined *practices alignment* by identifying a primary NAEP science or TEL practice (rated 1) and possibly a secondary practice (rated 2) that was aligned with each NGSS performance expectation.

3. **Data analysis**. Finally, the research team cleaned and aggregated the data from the panel and conducted the quantitative and qualitative analyses presented in this report. First, the final set of grouped and non-grouped objectives was used to determine the extent of "content overlap" between the NGSS and the NAEP science and TEL frameworks, with grouped objectives indicating areas of "content overlap" or the potential for content alignment. Next, "content alignment" was determined on the basis of the content similarity ratings of the grouped objectives. Aggregate ratings of "content alignment" were assigned when the objectives in a grouping were rated as "similar" (3 or 4) by at least two-thirds of the expert panelists. Grouped objectives that did not meet this criterion and non-grouped objectives were rated as "not similar" and treated as not aligned for content. Content alignment at the objective level was calculated in both directions (NGSS to NAEP and NAEP to NGSS). "Alignment at a lower or higher grade" in the science comparisons was based on alternative objectives at a different grade level proposed by the expert panel and confirmed by the research team lead; this rating was applied only for objectives rated as "not similar" at the corresponding grade level.

   The research team determined a final "practice alignment" for each performance expectation on the basis of the primary NAEP practice most frequently identified by the expert panelists, provided that at least three panelists agreed. Detailed content comparison descriptions supporting the quantitative data were prepared by the research team using the expert panel ratings on content similarity and practices alignment, as well as comments and a thorough review of the NGSS and NAEP framework documents.

[8] The science and TEL expert panel included seven curriculum and assessment experts with direct experience working on the NGSS and/or NAEP frameworks and assessments (see appendix A).

Mathematics comparisons

The mathematics comparisons were conducted in the same three steps as the science and TEL comparisons, though the details of the procedures differed because of the more restricted scope of the mathematics comparisons and the lack of explicit descriptions of mathematics requirements in the NGSS performance expectations (and the need to infer them).

To prepare the initial mapping document for the mathematics comparisons, the AIR research team used (1) the annotations in the NGSS that identified connections between individual performance expectations and specific Common Core State Standards in Mathematics (CCSS-M; Common Core State Standards Initiatives, 2010) and (2) the results of a separate alignment study between the CCSS-M and the NAEP mathematics framework to identify corresponding NAEP objectives.[9] The mapping document provided preliminary groupings of NGSS mathematics-related performance expectations with NAEP mathematics objectives based on the connections to the CCSS-M described in the NGSS. A mathematics expert panel[10] then (1) reviewed each NGSS performance expectation to determine the mathematics content and skills that might be involved in items that could be developed to assess it and (2) determined by consensus if the mathematics identified was covered in related NAEP mathematics objective(s) at the corresponding grade or at two adjacent grades in the NAEP framework (i.e., grades 4 and 8 or grades 8 and 12). This second step involved removing NAEP objectives across grades from the preliminary groupings or adding NAEP objectives to them. The outcome was a final set of NAEP mathematics objectives judged as "aligned" with each NGSS performance expectation, where "aligned" meant that the mathematics identified was included in NAEP. The AIR research team used the final set of aligned NAEP objectives to conduct the quantitative and qualitative analyses in this report, including detailed content comparisons of the mathematics-related performance expectations and the mathematics covered in aligned NAEP objectives from each content area and grade.

[9] The study of alignment between the NAEP mathematics framework and the CCSS-M was conducted by the NAEP Validity Studies panel (Hughes et al. 2013).

[10] The mathematics expert panel included three NAEP mathematics experts from AIR and one member with direct NGSS experience from the science and TEL panel; three of the four panelists also had experience in science education (see appendix A).

Exhibit 3 provides descriptions of the key terms that were defined in this section and are used throughout the Results.

Exhibit 3. Key terms

Content overlap is described by the percentage of NGSS and NAEP objectives that were grouped. Grouped objectives are those that cover related content at the corresponding grade level and that could be subsequently compared and rated for similarity to determine the degree of content alignment. Content overlap, therefore, indicates the *potential* for content alignment between the NGSS and NAEP science and TEL frameworks at specific grade levels.
Content alignment is described by the percentage of NGSS and NAEP objectives the expert panel rated as "similar." Content alignment reflects the grouped objectives in the NGSS and NAEP science and TEL frameworks judged as similar enough in depth, breadth, detail, and focus of content that they could lead to similar assessment items at the corresponding grade level. By definition, content alignment is never greater than content overlap.
Alignment at a lower or higher grade (or grade-level alignment) is described by the percentage of objectives rated as "not similar" at the corresponding grade that were identified as being aligned to an objective at a lower or higher grade in the counterpart framework. This was only done for the science comparisons and indicates content that is emphasized at different grades in the NGSS and the NAEP science framework.
Practices alignment is described by the percentage of NGSS performance expectations whose associated practices were aligned to a NAEP science or TEL practice. Practices alignment indicates to which primary NAEP science or TEL practice the NGSS performance expectations were aligned.
Alignment in mathematics is described by the percentage of NGSS performance expectations whose associated practices involved mathematics that was included in the 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 items based on the NGSS is included in the NAEP framework and at what grade level(s).

NOTE: The practices alignment and alignment in mathematics measures are only available in terms of the alignment of the NGSS to NAEP. Measures of content overlap, content alignment, and alignment at a lower or higher grade are available both in terms of the coverage of the NGSS by NAEP and the coverage of NAEP by the NGSS.

Results

The results that follow are presented in two sections: (1) key findings and (2) detailed findings and implications.

The *key findings* section focuses on the science and TEL comparisons because they can inform a key question of interest—how similar or different would assessments based on the NGSS and the NAEP science and TEL frameworks be—and because NGSS performance expectations are explicit in terms of the science and engineering content and practices to be compared. The mathematics results are not included in the key findings because the data do not lend themselves to such analysis—since the NGSS performance expectations do not explicitly identify the mathematics needed—and because the NGSS are not intended to guide the development of mathematics assessments. The mathematics results, described in the detailed findings, rather supplement the key findings by suggesting how assessments based on the NGSS might

compare with NAEP science and TEL assessments in terms of the level of mathematics and quantitative skills applied in science and engineering tasks. The *detailed findings* describe the results for each of the individual components of the study, including science, TEL, and mathematics.

Additionally, the exhibits in appendix B (organized by grade band and content domain) provide a summary of the comparisons of the NGSS performance expectations with the NAEP science and TEL frameworks. They identify which NGSS performance expectations cover content that overlaps with the NAEP science and TEL frameworks (i.e., those that were grouped with NAEP objectives at the corresponding grade level) and, of those, which were aligned (i.e., rated as similar). The exhibits also identify those performance expectations that were judged as covering content not included in NAEP at the corresponding grade level (i.e., not grouped with objectives in either the NAEP science or TEL framework).

Key findings

The key findings 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, they examine the degree of (1) content overlap, (2) content alignment, and (3) practices alignment.[11]

In sum, 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 variation in each measure by grade and content area. Practices alignment was uniformly strong, but the distribution of NGSS performance expectations across NAEP science and TEL practices differed from the emphasis across practices specified in the NAEP frameworks.

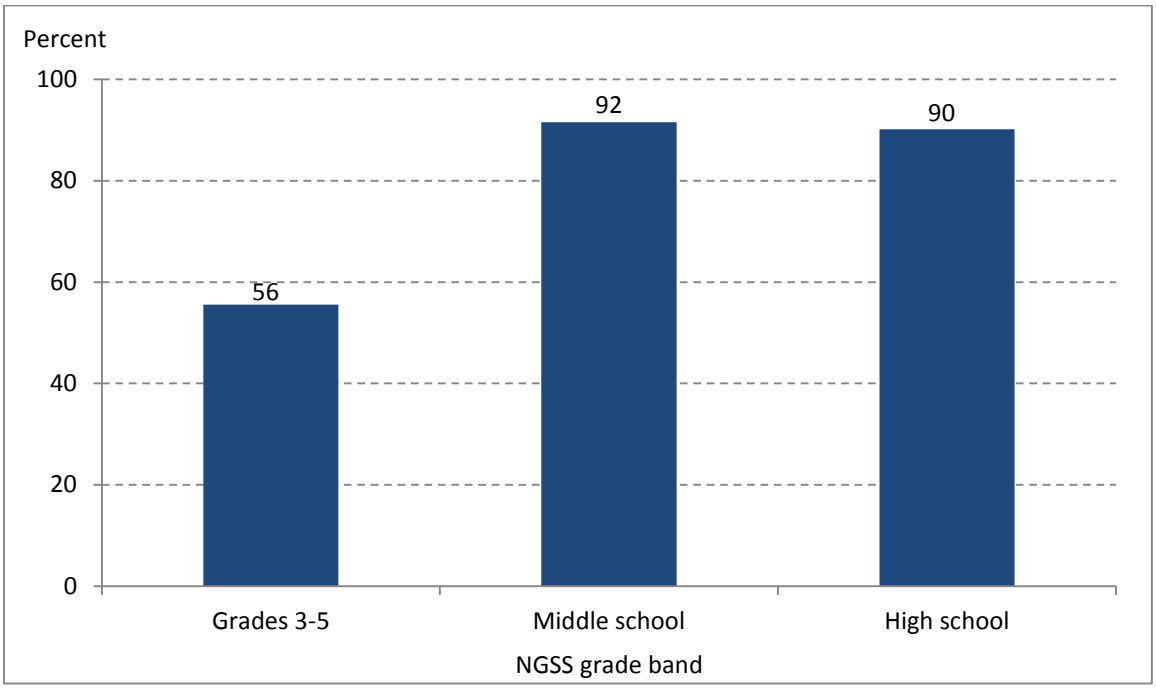
[11] See exhibit 3 for the definitions of these and other key terms used throughout the Results.

Content overlap

- Fifty-six percent of the NGSS performance expectations across all four content domains at the upper elementary level (grades 3–5) covered content that overlaps with NAEP science or TEL at grade 4 (see figure 1).

- 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.

Figure 1. Percentage of NGSS performance expectations grouped with objectives covering related content in the NAEP science and TEL frameworks at the corresponding grade level, by NGSS grade band



NOTE: NAEP grades 4, 8, and 12 correspond to the NGSS grade bands for grades 3–5, middle school, and high school, respectively. The percentages in the figure reflect (1) performance expectations in the sciences at grade 4, middle school, and high school that were grouped with related content in the NAEP science framework at the corresponding grades (4, 8 and 12, respectively); (2) a subset of the performance expectations in science with connections to engineering, technology, and applications of science (ETS) that were also grouped with related content in the NAEP TEL framework; and (3) performance expectations in engineering design in the three grade bands that were grouped with content in the NAEP TEL framework, but not the science framework. The 3–5 grade band also includes performance expectations in the sciences in grades 3 and 5 that were identified as covering content included in NAEP grade 4 objectives in science.

Content alignment

- Roughly half of the NGSS performance expectations across all four content domains 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, with none aligned to both.

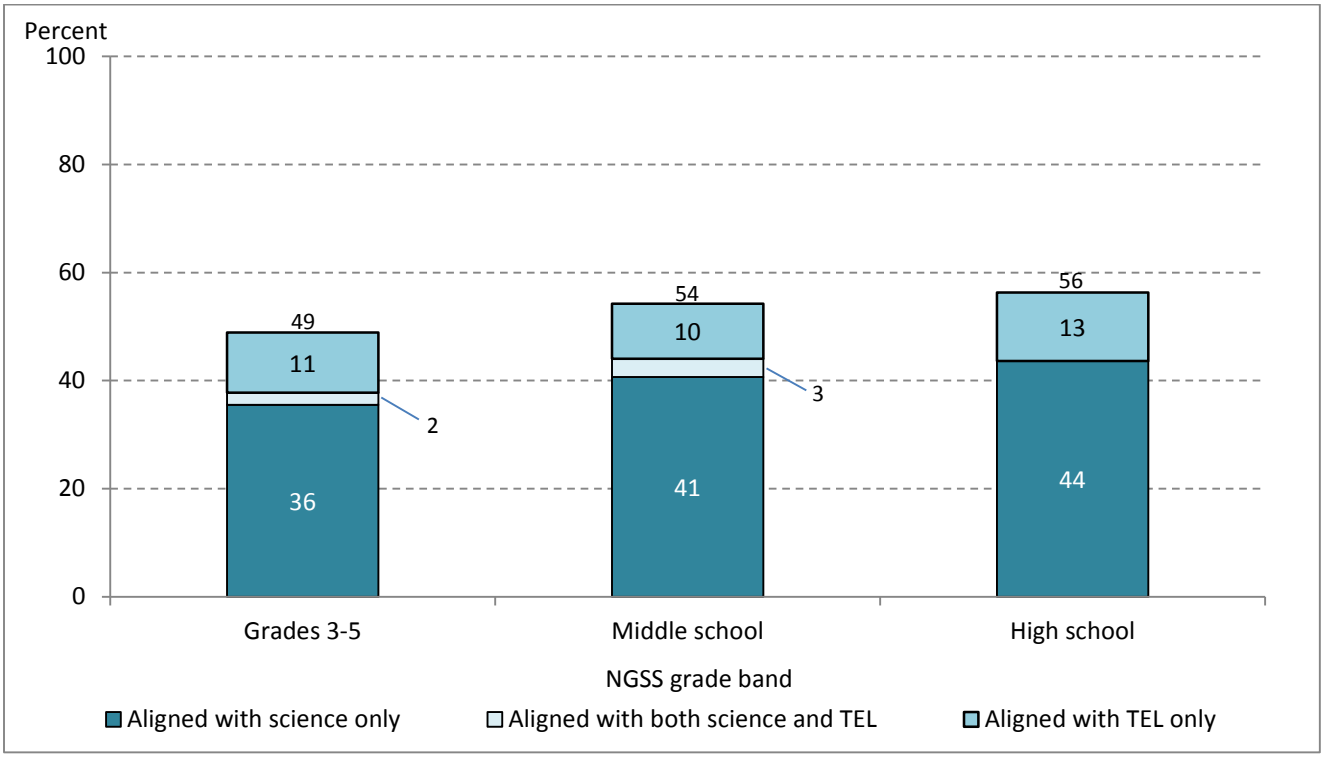
- In the sciences, looking only at the grade 4 NGSS performance expectations, 36 percent were aligned to the NAEP science framework at grade 4. An additional 21 percent were aligned to the NAEP science framework at grade 8.

- About one-half of NGSS 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 the corresponding grades 8 and 12, respectively. An additional 9 percent of middle school performance expectations were aligned to NAEP at a higher grade (grade 12), and 6 percent of high school performance expectations were aligned at a lower grade (grade 8).

- 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 (ETS), 86 percent of NGSS performance expectations in grades 3–5—including both those in engineering design and those in science 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 level. Rates of alignment were much higher for performance expectations in engineering design (from 75 to 100 percent) than for those in the sciences with connections to ETS (between 38 and 75 percent).

Figure 2. Percentage of NGSS performance expectations aligned with the NAEP science and TEL frameworks at the corresponding grade level, by NAEP framework and NGSS grade band



NOTE: NAEP grades 4, 8, and 12 correspond to the NGSS grade bands for grades 3-5, middle school, and high school, respectively. Content alignment is based on similarity ratings of groupings of NGSS performance expectations and NAEP objectives with related content at the corresponding grade level using a 4-point scale (from "substantially or wholly different" to "exactly or almost the same"). Content alignment is indicated when two-thirds or more of the expert panelists rated a specific grouping as similar (a rating of 3 or 4). The percentages in the figure are based on (1) performance expectations in the sciences at grade 4, middle school, and high school that were aligned with related content in the NAEP science framework only; (2) a subset of performance expectations in science with connections to engineering, technology, and applications of science (ETS) that were aligned with related content in both the NAEP science and TEL frameworks or in the TEL framework only; and (3) performance expectations in engineering design in the three grade bands that were aligned with content in the NAEP TEL framework only. The 3-5 grade band also includes performance expectations in the sciences in grades 3 and 5 that were identified as covering content included in NAEP grade 4 objectives in science. Detail may not sum to totals because of rounding.

Practices alignment

- Ninety-nine percent of NGSS performance expectations in the natural sciences were aligned with NAEP science practices and 81 percent of performance expectations in ETS were aligned with 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 *using science principles* (focused on applying knowledge 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)

Detailed findings and implications

The detailed findings describe the results of comparisons of the NGSS (1) across the NAEP science and TEL frameworks and (2) with each of the NAEP science, TEL, and mathematics assessment frameworks individually. This section also addresses, where appropriate, implications for how NGSS-based assessments might compare to NAEP assessments based on these findings.

Comparisons across the NAEP science and TEL frameworks

1. **Comparing the NGSS with both the NAEP science and TEL frameworks indicates substantial content overlap at the middle and high school levels, but less at the upper elementary level**. Again, content overlap is evidenced by the number of NGSS performance expectations that were grouped with NAEP objectives judged as covering related content, which indicates the potential for content alignment. (See table 1, which shows the number of NGSS performance expectations in each grade band that were grouped with NAEP objectives in the science framework, the TEL framework, and cumulatively across both frameworks.)

    - **At the upper elementary level, the content overlap between the NGSS and the NAEP science and TEL frameworks was moderate, but there were differences by NGSS content domain.** When considering the upper elementary level (grades 3–5), all three engineering design performance expectations overlapped with NAEP TEL at grade 4. Content overlap with NAEP science includes 9 (of 14) NGSS performance expectations in the sciences at grade 4 that were grouped with NAEP content statements at the same grade, as well as performance expectations from the adjacent grades (7 at grade 3 and 5 at grade 5) that overlapped with NAEP at grade 4.[12] This means half (21 of 42) of the performance expectations in the natural sciences (including physical sciences, life sciences, and Earth and space sciences) in the upper elementary grade band covered content that overlapped with NAEP science at grade 4. In addition, 4 science performance expectations with connections to ETS overlapped content in the TEL framework (3 of which were also grouped with NAEP science and 1 that was grouped with NAEP TEL only).

      Overall, across both the NAEP science and TEL frameworks, the content overlap with NAEP grade 4 reflects slightly more than half (25 of 45) of the NGSS performance expectations in the upper elementary grade band.[13] In addition, nearly half (14 of 33) of the performance

[12] Table 1 indicates the NGSS performance expectations in the upper elementary grade band at grade 4 (column 3), grade 3 (column 4), and grade 5 (column 5) that overlapped content in NAEP grade 4 objectives.

[13] Overall content overlap is the sum of columns 9 to 11 in table 1 for the relevant grade bands. This reflects NGSS performance expectations in the sciences grouped with NAEP science objectives, those in the sciences with connections to ETS grouped with NAEP TEL, and those in engineering design grouped with NAEP TEL only.

expectations in the K–2 grade band covered content that overlapped with NAEP at grade 4; these were all in science.

- **At the middle school level, there was a high degree of content overlap in the NGSS and NAEP.** The large majority of performance expectations in both the natural sciences and engineering design in middle school were grouped with related content in the NAEP grade 8 objectives in the science or TEL frameworks, as appropriate. All four middle school performance expectations in engineering design were grouped with NAEP TEL objectives at grade 8. Of the 55 middle school performance expectations in the natural sciences, 46 were grouped with NAEP science objectives at grade 8 (including 3 grouped with both science and TEL), and 6 performance expectations covered content in the NAEP grade 12 science framework, most of which were in physical sciences. Overall, more than 90 percent (54 of 59) of the NGSS performance expectations in middle school overlapped with content at grade 8 in the NAEP science or TEL framework.

- **At the high school level, the degree of content overlap between the NGSS and NAEP was also high.** The large majority of performance expectations in all content domains at the high school level were grouped with related content in the NAEP grade 12 science or TEL frameworks. All four performance expectations in engineering design overlapped with content in NAEP TEL, as did 56 of 67 in the natural sciences with NAEP science. Of the latter, 5 with connections to ETS overlapped with both NAEP frameworks. Only 15 percent (10 of 67) of the high school performance expectations in science covered content at a lower grade (grade 8) in the NAEP science framework, and these were fairly evenly distributed across the science content domains. Overall, 90 percent of high school performance expectations were grouped with NAEP objectives at grade 12 in the science or TEL frameworks.

Table 1. Number of NGSS performance expectations (PEs) grouped with NAEP science and TEL framework objectives, by NGSS grade band and content domain

NGSS grade band and content domain (1)	Total number of PEs in grade band (2)	PEs grouped with NAEP science framework objectives					PEs grouped with NAEP TEL framework objectives	Total PEs grouped with NAEP science or TEL objectives (within the same grade band)		
		Within the same grade band (by NGSS grade level)			In a different grade band (by NGSS grade level)					
		Corresponding grade in NAEP (3)	Lower grade than NAEP (4)	Higher grade than NAEP (5)	Lower grade than NAEP (6)	Higher grade than NAEP (7)	Corresponding grade in NAEP (8)	Science framework only (9)	TEL framework only (10)	Both science and TEL frameworks (11)
Grades K–2	33	†	†	†	14	†	†	†	†	†
Natural sciences[1]	30	†	†	†	14	†	†	†	†	†
Engineering design	3	†	†	†	†	†	†	†	†	†
Grades 3–5	45	9	7	5	4	†	7	18	4	3
Natural sciences[2]	42	9	7	5	4	†	4	18	1	3
Engineering design	3	†	†	†	†	†	3	†	3	†
Middle school	59	46	†	†	6	1	11	43	8	3
Natural sciences	55	46	†	†	6	1	7	43	4	3
Engineering design	4	†	†	†	†	†	4	†	4	†
High school	71	56	†	†	†	10	13	51	8	5
Natural sciences	67	56	†	†	†	10	9	51	4	5
Engineering design	4	†	†	†	†	†	4	†	4	†

† Not applicable.

[1] The K-2 grade band includes 30 grade-specific science performance expectations in the natural sciences: 10 in kindergarten, 9 in grade 1, and 11 in grade 2.

[2] The 3-5 grade band includes 42 grade-specific science performance expectations in the natural sciences: 15 in grade 3, 14 in grade 4, and 13 in grade 5.

NOTE: A subset of the total NGSS performance expectations (PEs) in each grade band was grouped with one or more content objective(s) from the NAEP science and/or NAEP TEL frameworks that covered related content at the corresponding grade level. Performance expectations in the natural sciences (physical sciences, life sciences, and Earth and space sciences) were compared with the NAEP science framework; a subset of these with connections to engineering, technology, and applications of science (ETS) were also compared with the NAEP TEL framework. Performance expectations in engineering design were compared with the NAEP TEL framework, but not to the NAEP science framework. NAEP grades 4, 8, and 12 correspond to the NGSS grade bands for grades 3-5, middle school, and high school, respectively. In the table, columns 3-5 indicate the number of PEs grouped with NAEP science content statements in the same grade band. Column 3 reflects PEs grouped with content statements at the corresponding grade level (grade 4, 8, or 12). For the upper elementary (grades 3-5), columns 4 and 5 reflect PEs from a lower or higher grade in the same grade band (grade 3 or 5, respectively) identified as covering content included in NAEP grade 4; these columns do not apply to middle school and high school. Columns 6 and 7 indicate the number of NGSS PEs identified by the expert panel as having alternative groupings with NAEP science content statements in a higher or lower grade band. The number of NGSS PEs that was grouped with NAEP TEL assessment targets at the corresponding grade level is shown in column 8. Columns 9-11 indicate the number of PEs that were grouped with NAEP objectives within the same grade band in the science and/or TEL framework combined, including those grouped with the science framework only (9), the TEL framework only (10), or both frameworks (11). Performance expectations that were grouped with objectives in both frameworks were those in the sciences with connections to ETS. The sum of columns 9-11 indicates content overlap with science and/or TEL and is the basis of the data shown in figure 1. The sum of columns 9 and 11 indicates content overlap with science (and is equivalent to the sum of columns 3–5); the sum of columns 10 and 11 indicates content overlap with TEL (and is equivalent to column 8).

2. **Content alignment between the NGSS and NAEP science and TEL frameworks was moderate at the upper elementary, middle, and high school grade levels.** Roughly half of the performance expectations in each grade band aligned to the NAEP science or TEL framework at the corresponding grades (see table 2 below). At the upper elementary level (grades 3–5), 22 of 45 NGSS performance expectations across content domains were aligned to either the NAEP science or TEL framework at grade 4, or both—with the majority (16) aligned to the science framework only. At the middle school level, 32 of 59 performance expectations were aligned to NAEP at grade 8, with 24 aligned to the science framework only. At the high school level, 40 of 71 performance expectations were aligned to NAEP at grade 12, with 31 aligned to the science framework only. In the natural sciences, the large majority of aligned performance expectations were to the science framework, but small numbers were aligned to the TEL framework only (2, 3, and 6 at the three grade levels, respectively) or aligned to both frameworks (1 at the upper elementary level and 2 at the middle school level). Performance expectations in science that aligned to the TEL framework or both the TEL and science frameworks were those with connections to ETS. In engineering design, performance expectations were only compared with the TEL framework (because they do not specify science content); thus, alignment was with the TEL framework only (all 3 performance expectations at grades 3–5 and 3 of 4 at the middle school and high school levels).

3. **The content and practices embodied in the NGSS performance expectations involving engineering design are not fully covered by either the NAEP science or NAEP TEL framework.** Performance expectations involving engineering design were grouped with NAEP TEL and those in the sciences involving design applications were grouped with NAEP science and aligned with the NAEP science practice of *using technological design*. However, assessment tasks involving engineering design resulting from the two programs could look quite different despite these similarities. One reason is that the NGSS requires the application of science concepts but the NAEP TEL assessment does not expect prior science content knowledge. (NAEP TEL provides background on the science concepts needed to be successful on the items and tasks measuring the engineering design process.) Furthermore, the practice of *using technological design* in NAEP science is restricted to the consideration of scientific criteria, constraints, and trade-offs in making design decisions, whereas the NGSS (and NAEP TEL) more fully reflect the engineering design process and include a broader range of considerations, such as social and economic factors (excluded in NAEP science).

Table 2. Number of NGSS performance expectations (PEs) aligned with NAEP science and TEL framework objectives, by NGSS grade band and content domain

NGSS grade band and content domain	Total PEs in grade band	PEs aligned with NAEP frameworks at the corresponding grade			Total PEs aligned with NAEP science or TEL frameworks at the corresponding grade
		Science framework only	Both science and TEL frameworks	TEL framework only	
Grades 3–5	45	16	1	5	22
Natural sciences[1]	42	16	1	2	19
Engineering design	3	†	†	3	3
Middle school	59	24	2	6	32
Natural sciences	55	24	2	3	29
Engineering design	4	†	†	3	3
High school	71	31	0	9	40
Natural sciences	67	31	0	6	37
Engineering design	4	†	†	3	3

† Not applicable.

[1] The 3-5 grade band in the natural sciences includes 15 performance expectations at grade 3, 14 at grade 4, and 13 at grade 5.

NOTE: Performance expectations (PEs) in the natural sciences (physical sciences, life sciences, and Earth and space sciences) were compared with the NAEP science framework; a subset of performance expectations with connections to engineering, technology, and applications of science (ETS) were also compared with the NAEP TEL framework. Performance expectations in engineering design were compared with the NAEP TEL framework, but not to the NAEP science framework. Content alignment is based on similarity ratings of groupings of NGSS PEs and NAEP objectives with related content at the corresponding grade level using a 4-point scale (from "substantially or wholly different" to "exactly or almost the same"). Content alignment is indicated when two-thirds or more of the expert panelists rated a specific grouping as similar (a rating of 3 or 4). NAEP grades 4, 8, and 12 correspond to the NGSS grade bands for grades 3-5, middle school, and high school, respectively. Science performance expectations in grades 3 and 5 were included if the expert panel proposed alternative groupings of NGSS PEs in those grades that covered content included in NAEP science objectives at grade 4.

Comparisons with the NAEP science framework

Detailed findings on the comparisons with the NAEP science framework include comparisons in both directions (NGSS compared with NAEP and NAEP compared with NGSS) that are focused on the corresponding grades (grade 4, grade 8/middle school, and grade 12/high school).[14] They also include examples of areas of similarity and difference at each grade level and results of similarity ratings at the content area and overall framework levels.

1. **There was substantial content overlap between the NGSS and the NAEP science framework.** At grade 4, middle school, and high school, more than three-quarters of the NGSS performance expectations (111 of 136) and more than two-thirds of the NAEP content statements (84 of 125) in the sciences were grouped with objectives in the counterpart framework that cover related content at the corresponding grade.

2. **The breadth of content covered in the NAEP framework at grade 4 is greater than that in the NGSS**. Breadth of content is indicated by the number of non-grouped objectives, since this represents content that is in one framework but not in its counterpart at the corresponding grade level

[14] This differs from the previous comparisons across the NAEP science and TEL frameworks, which presented results in only one direction (NGSS to NAEP) and for all three grades in the upper elementary grade band (3–5) in addition to the middle school and high school grade bands.

and thus is unique for that grade. Compared to the NGSS, NAEP had many more non-grouped objectives at grade 4 (23.5 compared to 5). The high proportion of non-grouped NAEP objectives at grade 4 is at least in part because the NGSS cover upper elementary content across three grades (grades 3–5), and some of the content in NAEP at grade 4 may be covered at a different grade in the NGSS (see finding 5 in this section). Breadth of content was more similar at middle school/grade 8 (11 non-grouped objectives in NAEP, in comparison with 9 in the NGSS) and at high school/grade 12 (6 in NAEP, compared to 11 in the NGSS).

3. **The degree of content alignment—or the proportion of objectives in the NGSS and NAEP that were judged as similar—varied across the three science content areas**. The NGSS and NAEP were the most similar in life sciences. Across all grades, the alignment in this content area to the counterpart framework at the corresponding grade level was the highest (ranging from 36 to 81 percent of NAEP content statements aligned to the NGSS). In contrast, content in the NGSS and NAEP was the most distinct in physical sciences. Alignment in this content area was the lowest (ranging from 13 to 61 percent of NAEP content statements aligned to the NGSS). Physical sciences also had the highest number of non-grouped objectives, reflecting unique content at the corresponding grade. As a whole, life sciences was the only content area rated as similar at two grades (grades 8 and 12). Physical sciences was rated as similar only at grade 12, and Earth and space sciences was rated as similar only at grade 8. None of the content areas was rated as similar at grade 4.

4. **The degree of content alignment varied across grade levels.** In general, the degree of content alignment increased with the grade levels (see table 3 below). These results ultimately show how similar (or different) assessments based on the NGSS may be compared with NAEP science assessments; topics that were similar in both frameworks suggest areas where NAEP may include assessment items or tasks that measure the performance expectations in the NGSS at the corresponding grade.

    - **Content alignment between the NGSS and NAEP was low at grade 4**. Slightly more than one-third of the NGSS performance expectations at grade 4 were judged as aligned to NAEP, and slightly less than one-quarter of the NAEP content statements were judged as aligned to the NGSS. It should be pointed out that grade 4 represents only one grade in the 3–5 grade band in the NGSS, so the NGSS's upper elementary content may be underrepresented in the comparisons.[15] Examples of topics that were judged as similar at grade 4 include forms of energy, structures and functions in organisms, effects of weathering and erosion, and human use of natural resources.

    - **About half of the objectives in the NGSS and NAEP were aligned at grade 8/middle school**. Just under half of the NGSS performance expectations at the middle school level (47 percent) and just over half of the NAEP content statements at grade 8 (56 percent) were judged as aligned to

[15] When alternative groupings of NGSS performance expectations from the grades adjacent to grade 4 (i.e., grades 3 and 5) are considered, the potential content alignment with the NAEP grade 4 framework increases (see finding 1 in comparisons across the NAEP science and TEL frameworks).

the counterpart framework at the corresponding grade level. Some topics that were rated as similar in the two frameworks include evidence of chemical reactions, the particulate model of matter, energy transfer, organs and organ systems in multicellular organisms, photosynthesis, interactions between organisms in ecosystems, evidence for relatedness of organisms, natural selection, the model of the solar system, evidence from rock strata and fossils to measure geologic time, evidence of lithospheric plate movement, patterns of atmospheric movements, and human impacts on the environment.

- **Content alignment was higher for NAEP to NGSS than for NGSS to NAEP at grade 12/high school**. About half of the NGSS performance expectations at the high school level (46 percent) were judged as aligned to the NAEP grade 12 framework. In contrast, 71 percent of the NAEP content statements at grade 12 were judged as aligned to the NGSS at the high school level. Examples of topics that were rated as similar in the NGSS and NAEP include patterns in the periodic table to explain chemical reactivity, nuclear fission and fusion, conservation of momentum, gravitational and electric forces, the role of DNA, complex interactions in ecosystems and energy flow through trophic levels, natural selection and evolution, evidence for the Big Bang theory, the theory of plate tectonics, and energy input and output in Earth systems.

Table 3. Content and grade-level alignment between NGSS performance expectations and NAEP science content statements, by grade level

Grade level (1)	NGSS to NAEP		NAEP to NGSS	
	Number (2)	Percentage (3)	Number[1] (4)	Percentage (5)
Grade 4	14	100	33.0	100
Similar (at corresponding grade)	5	36	7.5	23
Not similar				
Aligned at a lower grade	†	†	15.5	47
Aligned at a higher grade	3	21	4.0	12
Not aligned	6	43	6.0	18
Grade 8 (middle school)	55	100	43.0	100
Similar (at corresponding grade)	26	47	24.0	56
Not similar				
Aligned at a lower grade	0	0	0.0	0
Aligned at a higher grade	5	9	7.0	16
Not aligned	24	44	12.0	28
Grade 12 (high school)	67	100	49.0	100
Similar (at corresponding grade)	31	46	35.0	71
Not similar				
Aligned at a lower grade	4	6	1.5	3
Aligned at a higher grade	†	†	†	†
Not aligned	32	48	12.5	26

† Not applicable. Since grade 4 is the lowest grade in the NAEP framework, "Aligned at a lower grade" is not applicable for the alignment of the NGSS to NAEP at grade 4. "Aligned at a higher grade" is not applicable at grade 12.

[1] For NAEP content statements that were split, each part contributed a value of 0.5 to the number. (For a full explanation, see general note below.)

NOTE: Content alignment is based on similarity ratings of groupings of NGSS performance expectations (PEs) and NAEP content statements with related content at the corresponding grade level using a 4-point scale (from "substantially or wholly different" to "exactly or almost the same"). Data are presented for NGSS PEs aligned with NAEP (columns 2 and 3) and NAEP content statements aligned with NGSS PEs (columns 4 and 5). "Similar (at corresponding grade)" indicates that two-thirds or more of the expert panelists rated a specific grouping as similar (a rating of 3 or 4). "Not similar" includes groupings that were rated as "not similar" as well as non-grouped objectives (NGSS PEs or NAEP content statements). Each NGSS performance expectation maps to a single grouping, but NAEP content statements may map to multiple groupings. In some cases, a NAEP content statement was split into two parts, and each part was then mapped to one or more groupings, with the corresponding rating being weighted at half the value of a full content statement's rating (see column 4). The "not similar" category is further expanded to indicate the objectives that were aligned at a lower or higher grade versus those that were not aligned at any grade in the other framework. Detail may not sum to totals because of rounding.

5. **The NGSS emphasized some content at different grades than the NAEP framework.** Some content that was not similar at the corresponding grade was aligned at a higher or lower grade in the other framework. In general, the percentage of objectives aligned at a different grade was low, reflecting no more than one-fifth of objectives. The one exception was for NAEP at grade 4, where almost 60 percent of content statements were aligned at other grades in the NGSS. The percentage aligned at a different grade decreased over the grade levels for both the NGSS and NAEP.

    - **At grade 4, 47 percent of NAEP objectives aligned at a lower grade in the NGSS (i.e., grade K–3) and 12 percent aligned at a higher grade (i.e., grade 5 or above)**. Some topics in NAEP at grade 4 included at a lower grade in the NGSS are basic properties of sound and light, magnetic properties, balanced and unbalanced push/pull forces, life cycles of organisms, inheritance and variation of traits in organisms, the Sun as a source of energy for the Earth, daily and seasonal weather changes, and daily patterns in the apparent movement of the Sun and the Moon. NAEP grade 4 content included at a higher grade in the NGSS includes mixtures and pure substances, properties and changes in states of matter (solid, liquid, and gas), the interdependence of organisms, the force of the Earth's gravity on objects, and the Moon's phases and monthly cycle. Of the NGSS performance expectations at grade 4, 21 percent aligned at grade 8 in NAEP, including those on such topics as the relationship between speed and energy, energy changes during collisions, and the use of topographic maps.[16]

    - **At the middle school level, 16 percent of objectives in NAEP and 9 percent in the NGSS aligned at the higher grade in the counterpart framework (grade 12/high school); none aligned at lower grades**. Examples of NAEP grade 8 topics not included until high school in the NGSS include the periodic table, cell differentiation, and the Earth's layers and magnetic field. In contrast, the formula for electric force, genetic variation within populations and the effects of mutation, and exothermic and endothermic reactions were included in middle school in the NGSS but not until grade 12 in NAEP.

    - **At the high school level, 3 percent of NAEP and 6 percent of NGSS objectives aligned at lower grades in the counterpart framework.** The NAEP high school topics included at a lower grade in the NGSS include the effects of gene mutation (middle school) and energy transfer during collisions (middle school and grade 4). Topics included in the NGSS at high school but at grade 8 in NAEP are causes and effects of climate change, the effect of the availability of biotic and abiotic resources on populations in an ecosystem, and interacting organ systems in multicellular organisms.

6. **Both the NGSS and NAEP included objectives at each grade level that cover unique content.** This reflected non-grouped objectives with content that was in one framework but not in its counterpart at any grade. Some examples of unique content in NAEP include introductory knowledge of relative motion (grade 4), properties of acids and bases (grade 8), and different types of motion (translation, rotation, and vibration) of particles and macroscopic objects (grade 12). Examples of unique content in the NGSS include knowledge of the senses (grade 4), the role of brain processing

[16] Alignment to a lower grade in NAEP was not possible since grade 4 is the lowest grade in the framework.

(middle school), and chemical reaction rates and chemical equilibrium (high school). In addition, the disciplinary core idea of "waves and their applications in technologies for information transfer" is included in NGSS performance expectations at all three grade levels but is not covered in a comparable way in NAEP. The unique content, together with content that was related but judged as not aligned at any grade in the counterpart framework, represented between 43 and 48 percent of NGSS performance expectations and between 18 and 28 percent of NAEP content statements that were "not aligned" across grades. These reflect areas where each program can contribute different information about student outcomes.

7. **Across grades, all but one of the NGSS performance expectations was aligned with a primary NAEP science practice**. In other words, the NGSS performance expectations were within the perceived scope of NAEP's practice requirements. Certain NGSS practices aligned particularly well with the NAEP practices of *using science principles* (e.g., developing and using models, constructing explanations, and engaging in argument from evidence), *using scientific inquiry* (e.g., planning and carrying out investigations and analyzing and interpreting data), and *identifying science principles* (e.g., obtaining, evaluating, and communicating information). There was also alignment between the engineering-specific components of the NGSS practices (defining problems and designing solutions) and the NAEP practice of *using technological design.* However, the full engineering design process as described in the NGSS is not reflected to the same extent in the NAEP science framework description of this practice.

8. **The majority of NGSS performance expectations were aligned with the NAEP practice of *using science principles.*** Sixty percent of NGSS performance expectations across grades aligned to NAEP's *using science principles*, followed by 22 percent aligned to *using scientific inquiry*, 13 percent aligned to *using technological design*, and 4 percent aligned to *identifying science principles*. In contrast, with some variation by grade, the NAEP framework specifies that between 20 and 30 percent of the science assessment is allocated to *identifying science principles*, and between 30 and 40 percent is allocated to *using science principles*. At all grades, 30 percent is allocated to *using scientific inquiry*, and 10 percent is allocated to *using technological design*. Therefore, assessments based on the NGSS would differ from NAEP assessments with respect to the coverage of the practices, with greater emphasis in the NGSS on *using science principles* (schematic knowledge, or knowing why) and very little emphasis on *identifying science principles* (declarative knowledge, or knowing that). The emphasis on *using scientific inquiry* may also be somewhat less in an NGSS-based assessment than in a NAEP assessment, particularly at grade 12, where only 18 percent of NGSS performance expectations were aligned to this practice.

9. **NGSS and NAEP science were rated as not similar at all grades at the overall framework level when both content and practices were considered together.** These overall framework ratings reflect the expert panel's perception that although the NGSS performance expectations were aligned to the NAEP science practices, they often were more extensive than what would be expected on the basis of the descriptions of the practices in the NAEP framework when applied to specific NAEP content statements.

Comparisons with the NAEP TEL framework

Detailed findings on the comparisons with the NAEP TEL framework include comparisons in both directions (NGSS compared with NAEP and NAEP compared with NGSS) at the corresponding grade levels (grade 4/grades 3–5, grade 8/middle school, and grade 12/high school). The percentages described are based on the NGSS performance expectations in engineering, technology and applications of science (ETS), including engineering design as well as in the sciences with connections to ETS.[17] Findings include examples of areas of similarity and difference across grades and content areas in the NGSS and NAEP TEL framework.

1. **Much of the NGSS's content in engineering, technology, and the application of science (ETS) is covered in the NAEP TEL framework**. The NGSS have a total of 42 performance expectations in ETS across the upper elementary grade band (grades 3–5), middle school, and high school, which were compared with the NAEP TEL framework. Nearly three-quarters of these were grouped with NAEP objectives covering related content at the corresponding grade level. Of those that were grouped, about three-quarters were judged as similar for content. These findings indicate substantial content overlap between the NGSS and NAEP TEL, and more than half of the NGSS performance expectations in ETS across grades aligned for content. Content alignment, however, varied across grades (see table 4), with 86 percent of performance expectations aligned with NAEP at grade 4 in comparison with 53 percent at grade 8 and 45 percent at grade 12.

[17] This is in contrast to the percentages described in the previous findings in comparisons across the NAEP science and TEL frameworks, which were based on all NGSS performance expectations in each grade band.

Table 4. Content alignment of NGSS performance expectations in engineering, technology and applications of Science (ETS) with NAEP TEL assessment targets, by grade band and content domain

Content domain	NGSS performance expectations aligned with NAEP TEL assessment targets					
	Grades 3-5[1]		Middle school		High school	
	Number	Percentage	Number	Percentage	Number	Percentage
Engineering design	3	100	4	100	4	100
Similar (at corresponding grade)	3	100	3	75	3	75
Not similar	0	0	1	25	1	25
Science - with connections to ETS	4	100	11	100	16	100
Similar (at corresponding grade)	3	75	5	45	6	38
Not similar	1	25	6	55	10	63
All content domains	7	100	15	100	20	100
Similar (at corresponding grade)	6	86	8	53	9	45
Not similar	1	14	7	47	11	55

[1] Includes NGSS performance expectations in science at grade 4 and in engineering design in the 3-5 grade band.

NOTE: Content alignment is based on similarity ratings of groupings of NGSS performance expectations (PEs) and NAEP TEL assessment target(s) with related content using a 4-point scale (from "substantially or wholly different" to "exactly or almost the same"). "Similar" indicates that two-thirds or more of the expert panelists rated a specific PE and NAEP assessment target(s) grouping at the corresponding grade level as similar by assigning a rating of 3 or 4. "Not similar" includes grouped NGSS PEs that were rated as "not similar" as well as non-grouped PEs. Data are shown separately for NGSS PEs from "Engineering Design" and for PEs from the science disciplines with connections to "Engineering, Technology, and Applications of Science" (ETS), as well as overall across both content domains. Detail may not sum to totals because of rounding.

2. **In contrast, NAEP TEL covers a much broader range of content than what is included in the NGSS performance expectations in ETS**. The NAEP TEL framework includes 141 assessment targets (47 at each grade), which is more than three times the number of NGSS performance expectations in ETS. More than three-quarters of the NAEP TEL assessment targets across grades were non-grouped, indicating unique content that is not included in the NGSS performance expectations at the corresponding grade level. While more than four-fifths of the grouped assessment targets were judged as similar to the NGSS, this reflects less than one-quarter of TEL assessment targets aligned in total. Content alignment of NAEP TEL to the NGSS was low across grades, with 13 percent of TEL assessment targets at grade 4, 17 percent at grade 8, and 28 percent at grade 12 aligned to NGSS performance expectations at the corresponding grade levels. These findings are consistent with the different purposes of the NGSS and NAEP TEL. ETS is just one of four content domains in the NGSS contributing (ultimately) to a science assessment, whereas NAEP TEL is an entire framework devoted to the assessment of technology and engineering literacy.

3. **The NGSS and NAEP TEL framework were most closely aligned in the area of engineering design across the three NAEP grades**. Three-quarters or more of the NGSS performance expectations in engineering design (as well as the majority of science performance expectations involving design applications) were judged as similar to the NAEP framework at the corresponding grade level, specifically the TEL engineering design subarea of design and systems. Topics that were similar in the two frameworks across grades included identifying design criteria and constraints, generating and comparing multiple design solutions, and developing and testing models, including gathering data to improve the design. The NGSS and NAEP TEL include similar expectations in terms of the level of sophistication at each grade, with more focus on evaluating the fit of competing solutions to meet criteria and constraints by middle school and on applying these skills to analyze global challenges, consider the impacts of technology on society and the environment, and address complex, real-world problems by high school.

4. **Alignment of the NGSS to the NAEP TEL framework was lower for performance expectations in the sciences with connections to ETS.** More than half of these performance expectations at the middle and high school levels did not align with NAEP TEL objectives at grade 8 (55 percent) and grade 12 (63 percent). These performance expectations require the application of specific science concepts. This is inherent in the NGSS's grounding of some ETS performance expectations in the natural science disciplines, which are not part of the NAEP TEL framework.

5. **Both the NGSS and NAEP TEL at the middle and high school levels include the effects of technology on society and the natural world.** They include the impact of technology on society and the environment and the consideration of societal and environmental impacts in making design decisions. This is a disciplinary core idea in the NGSS and included in the NAEP assessment area of technology and society. Five TEL assessment targets in technology and society at grade 12 and two assessment targets at grade 8 that were judged as similar to NGSS performance expectations at the corresponding grade levels covered this content.

6. **NAEP TEL includes unique content in all three assessment areas that is not covered in the NGSS performance expectations.** Objectives in NAEP TEL at all three grades cover a range of engineering and technology concepts and abilities not explicitly included in the NGSS performance expectations. For example, the TEL design and systems assessment area includes unique content in the subareas of nature of technology, systems thinking, and maintenance and troubleshooting. In the assessment area of technology and society, there is unique content in the subareas of interaction of technology and humans; effects of technology on the world of information and knowledge; and ethics, equity, and responsibility. While many of the concepts in these areas may underlie some of the disciplinary core ideas, practices, and cross-cutting concepts in the K–12 Framework (NRC 2012), there are no specific performance expectations in the NGSS related to these concepts. Also, most content in NAEP's assessment area of information and communication technology (ICT) is unique to NAEP TEL. While ICT knowledge and skills may be applied when demonstrating the scientific and engineering practices, this is not a focus in the NGSS; performance expectations in the NGSS do not explicitly require the abilities covered in this assessment area in NAEP TEL.

7. **The scientific and engineering practices in the NGSS performance expectations in ETS did not cover the full range of practices described in the NAEP TEL framework**. Eighty-one percent (34 of 42) of the performance expectations in ETS across grades mapped to a primary NAEP technology and engineering practice. Of these, more than three-quarters were concentrated in the NAEP practice of *developing solutions and achieving goals*, with few performance expectations in the two other NAEP practices (*understanding technological principles* and *communicating and collaborating*).

Comparisons with the NAEP mathematics framework

Detailed findings on the comparisons with the NAEP mathematics framework present the percentage of NGSS performance expectations aligned with NAEP mathematics objectives at the corresponding grade or in two adjacent grades in the NAEP framework (i.e., grades 4 and 8 or grades 8 and 12). The percentages described are based on the NGSS performance expectations in the sciences and engineering design that involved mathematics-related practices, which represented nearly all performance expectations.

1. **Most NGSS performance expectations involving mathematics were aligned to objectives in the NAEP mathematics framework**. All of the mathematics-related performance expectations at grade 4 and at least 87 percent at the middle and high school levels were aligned to NAEP objectives (see table 5).

2. **A significant percentage of the mathematics-related NGSS performance expectations at grades 4 and 8 were aligned with objectives at both the corresponding grade and the next higher grade in the NAEP framework**. Ninety-two 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 grades 4 and 8. Twenty-seven 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 grades 8 and 12. This means that items 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 assessment.

3. **Overall, these findings could represent a significant difference in the level of mathematics and quantitative skills in NGSS-based assessments than in the NAEP science assessments**. The NAEP science framework emphasizes qualitative or semi-quantitative understanding (e.g., understanding mathematical relationships such as proportionality rather than the formulaic use of equations), particularly at grades 4 and 8, and also specifies that the mathematics demands of science assessment items should be at or below grade level. In addition, calculators are not allowed in the current NAEP science assessment, which limits the level of mathematical calculations that can be required in items.[18]

[18] Calculators were not allowed in the 2015 paper-and-pencil NAEP science assessment; however, this could be reevaluated in the future as NAEP transitions to digitally-based assessments.

Table 5. Number and percentage of mathematics-related NGSS performance expectations (PEs) aligned with NAEP mathematics objectives, by NGSS grade band and NAEP grade level

NGSS grade band (1)	Total mathematics-related NGSS PEs (2)	NGSS PEs aligned with NAEP mathematics objectives (by NAEP grade level)					
		Grade 4 only (3)	Grades 4 and 8 (4)	Grade 8 only (5)	Grades 8 and 12 (6)	Grade 12 only (7)	Not aligned (8)
Grades 3-5[1]							
Number	13	1	12	†	†	†	0
Percent of total	100	8	92	†	†	†	0
Middle school							
Number	52	†	†	31	14	†	7
Percent of total	100	†	†	60	27	†	13
High school							
Number	59	†	†	†	8	49	2
Percent of total	100	†	†	†	14	83	3

† Not applicable.

[1] Includes NGSS performance expectations in science at grade 4 and in engineering design in the 3-5 grade band.

NOTE: Column 2 displays the total number and percentage of NGSS PEs involving mathematics-related practices at each grade band. Columns 3 through 7 indicate the number and percentage of PEs that were judged by the expert panel as involving mathematics included in one or more mathematics objectives in the NAEP framework (either at the corresponding grade or at two adjacent grades in the framework). Column 8 indicates PEs not aligned with any NAEP mathematics objective. Detail may not sum to totals because of rounding.

Conclusions

This study provided information primarily on the areas of similarity and difference between the NGSS and the NAEP frameworks in science and TEL. In particular, it described the extent of content overlap, reflecting the potential for content alignment, as well as the actual content alignment as determined by the degree of content similarity. The study showed that, despite their differences in goals, there were similarities between the NGSS and NAEP science and TEL. Overall, 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 variations in each measure by grade and by framework.

In terms of content overlap specifically, the study found that (1) about half of the NGSS performance expectations in the upper elementary grade band (3–5) covered content that overlaps with NAEP science or TEL at grade 4 and (2) 90 percent or more of the 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. In terms of content alignment, the study found that when looking across content domains at the upper elementary, middle, and high school grade levels, alignment was moderate, with roughly half the performance expectations aligned to NAEP science or TEL at each grade level. When looking only at the performance expectations in science, the content alignment of the NGSS to NAEP science was low at grade 4 (36 percent) and moderate at the middle school and high school levels (about half at each grade level). When looking only at the performance expectations in engineering, technology, and applications of science, content alignment was high for NGSS performance expectations in engineering design (at least 75 percent at

each grade level), but lower for those in the sciences with connections to ETS, especially at the upper grades (as low as 38 percent).

The study also examined the alignment of NGSS performance expectations with the NAEP science and TEL practices. Practices alignment was uniformly high (99 percent aligned to NAEP science and 81 percent aligned to NAEP TEL), but the distribution of NGSS performance expectations across NAEP science and TEL practices differed from the emphasis across practices specified in the NAEP frameworks. Other analyses related strictly to the science comparisons provided detail on content alignment to other grade levels (NGSS to NAEP and NAEP to NGSS), differences in content alignment by content areas, and alignment at the overall framework level.

Finally, the study provided information to supplement the science and TEL comparisons on the extent to which performance expectations in the NGSS involved mathematics that was included in the NAEP mathematics framework and at which grade(s). The findings suggest that the NGSS at grade 4 and middle school may require some mathematics that is beyond the corresponding grade level in the NAEP mathematics framework, which is in contrast to NAEP science and TEL assessments which require mathematics at or below the corresponding grade level.

It is important to keep in mind that this is a framework comparison study. While the framework comparison results have some implications for how NGSS-based assessments might compare with NAEP assessments, future studies that compare the content of actual assessments based on these frameworks would provide a more complete picture of how well the NAEP and NGSS-based assessments are aligned. The results of the framework comparison study can inform the nature and scope of such studies.

References

Common Core State Standards Initiative**.** (2010). *Common Core State Standards for Mathematics*. Retrieved August 29, 2014, from http://www.corestandards.org/Math.

Gattis, K., Rosenberg, S., Neidorf, T., Zhang, J., Guile, S., and McNeely, M. (2013). *A Comparison of the 2011 Grade 8 NAEP and TIMSS Mathematics and Science Frameworks* (NCES 2013-462). U.S. Department of Education. Washington, DC: National Center for Education Statistics. Retrieved February 10, 2015, from http://nces.ed.gov/nationsreportcard/subject/about/pdf/naep_timss_framework_comparison.pdf

Hughes, G.B., Daro, P., Holtzman, D., and Middleton, K. (2013). *A Study of the Alignment Between the NAEP Mathematics Framework and the Common Core State Standards for Mathematics (CCSS-M)*. Retrieved January 28, 2014, from http://www.air.org/resource/examining-content-and-context-common-core-state-standards-first-look-implications-national.

National Assessment Governing Board (NAGB). (2013). *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress*. (Pre-publication Edition). Washington, DC.

National Assessment Governing Board (NAGB). (2014a). *Mathematics Framework for the 2015 National Assessment of Educational Progress*. Washington, DC: U.S. Government Printing Office.

National Assessment Governing Board (NAGB). (2014b). *Science Framework for the 2015 National Assessment of Educational Progress*. Washington, DC: U.S. Government Printing Office.

National Research Council (NRC). (2012). *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Research Council (NRC). (2014). *Developing Assessments for the Next Generation Science Standards*. Washington, DC: The National Academies Press.

National Research Council (NRC). (2015). *Guide to Implementing the Next Generation Science Standards*. Washington, DC: The National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC. The National Academies Press.

Appendix A: List of Expert Panelists and AIR Research Team Members

Science and TEL Expert Panel

Alicia Alonzo
Michigan State University
College of Education
Dept. of Teacher Education
East Lansing, MI

Rodger Bybee
Director Emeritus
Biological Sciences Curriculum Study *(Retired)*
Golden, CO

George DeBoer
American Association for the Advancement of Science
Deputy Director, Project 2061
Washington, DC

Jacob Foster
Director of Science and Technology/Engineering
Massachusetts Dept. of Elementary and Secondary Education
Malden, MA

Brett Moulding
Director, Building Capacity for State Science Education
Ogden, UT

Kathleen Scalise
Educational Testing Service
Princeton, NJ

Jacqueline Smalls
Science Education Manager
Center for Inspired Teaching
Washington, DC

Mathematics Expert Panel[1]

Alka Arora
American Institutes for Research
Washington, DC

Kim Gattis
American Institutes for Research
Washington, DC

Will (Tad) Johnston
American Institutes for Research
Washington, DC

Jacqueline Smalls
Science Education Manager
Center for Inspired Teaching
Washington, DC

[1] The mathematics expert panel included both internal AIR experts in NAEP mathematics as well as an external panelist from the science and TEL expert panel with expertise on the NGSS. Alka Arora and Kim Gattis were part of the larger AIR research team in addition to serving on the mathematics panel to review the preliminary mapping document (prepared by other AIR research team staff) and identify NAEP mathematics objectives that were aligned with NGSS performance expectations.

AIR Research Team

The AIR research team was responsible for designing and implementing the study; preparing the content mapping documents; convening, facilitating and documenting results from the expert panel meetings; conducting data analyses; and writing the report.

Alka Arora
Senior Researcher

Markus Broer
Principal Psychometrician/Statistician

Kim Gattis
Principal Researcher

Sarah Guile
Test Development Associate

Juliet Holmes
Research Assistant

Sophie Jablansky
Intern

Austin Lasseter
Senior Researcher

Teresa Neidorf
Principal Researcher (study lead)

Emily Pawlowski
Research Associate

Karin Sather
Intern

Maria Stephens
Senior Researcher

Yan Wang
Senior Psychometrician/Statistician

Jiao Yu
Research Associate

Appendix B. A Summary of the Comparison of the NGSS Performance Expectations to the NAEP Science and TEL Assessment Frameworks

Appendix B summarizes the comparisons of the NGSS performance expectations from the four content domains to the NAEP science and TEL assessment frameworks. The appendix contains three exhibits—one for each grade band in the NGSS that was compared with the corresponding grade in NAEP—as follows:

- Exhibit B-1: NGSS performance expectations in the 3–5 grade band compared with the NAEP assessment frameworks at grade 4
- Exhibit B-2: NGSS performance expectations in the middle school grade band compared with the NAEP assessment frameworks at grade 8
- Exhibit B-3: NGSS performance expectations in the high school grade band compared with the NAEP assessment frameworks at grade 12

These exhibits are organized by content domain (physical sciences, life sciences, Earth and space sciences, and engineering design). In each content domain, they identify which NGSS performance expectations cover content that overlaps with the NAEP science and/or TEL assessment frameworks (i.e., those that were grouped with NAEP objectives at the corresponding grade level) and, of those, which were rated as "similar" or "not similar" for content. The exhibits also identify those performance expectations that were judged as covering content not included in NAEP at the corresponding grade level (i.e., not grouped with objectives in either the NAEP science or TEL framework).

The following bullets describe the information included in each exhibit, by column or sets of columns:

- **Disciplinary core ideas in each content domain**: The NGSS include a set of disciplinary core ideas (DCIs) in each content domain, which are shown in the first column of the exhibits. These are identified by codes that indicate the content domain and a sequential DCI number:

  Physical sciences (PS): PS1–PS4

  Life sciences (LS): LS1–LS4

  Earth and space sciences (ESS): ESS1–ESS3

  Engineering design (ETS):[1] ETS1

- **NGSS performance expectations (PEs)**:[2] For each disciplinary core idea, the NGSS include a set of grade-specific (or level-specific) performance expectations that are listed in the second column of

[1] The NGSS content domain of engineering, technology, and applications of science (ETS) includes two disciplinary core ideas: engineering design (ETS1) and links among engineering, technology, science, and society (ETS2). Engineering design includes performance expectations covering ETS1. Both ETS1 and ETS2 are reflected in a subset of the performance expectations in the sciences with connections to ETS.

each exhibit. Each NGSS performance expectation has a unique identifier that identifies the grade or grade band (e.g., 4, 3–5, MS, or HS), the DCI (e.g., LS1), and a sequential number within the DCI (e.g., 1, 2, 3). For example, the first DCI in life sciences (LS1) includes two PEs at grade 4 (4-LS1-1 and 4-LS1-2), eight PEs at the middle school level (MS-LS1-1 through MS-LS1-8), and seven PEs at the high school level (HS-LS1-1 through HS-LS1-7). All disciplinary core ideas are covered across each grade band (3–5, middle school, and high school); however, each DCI is not covered at every individual grade in elementary school (e.g., LS3 does not include any PEs at grade 4, though it does at grade 3.) For the 3–5 grade band, all grade 4 PEs in science are listed. Some PEs at grades 3 and 5 are also listed if the panel identified PEs at these grades that cover content included in NAEP grade 4 science objectives. Grade 5 PEs may include content somewhat beyond NAEP grade 4, but reflect overlapping content in the disciplinary core ideas that are not included at grade 4 in the NGSS.

- **Grouped with NAEP science**: The next pair of columns in each exhibit includes checkboxes to indicate which NGSS PEs in the sciences were grouped with NAEP science objectives that cover related content at the corresponding grade level and whether these were rated as "similar" or "not similar" for content. A rating of "similar" means that two-thirds or more of the panelists rated a specific grouping as "exactly or almost the same" or "quite similar, but with some differences." If this criterion was not met, then the PE was rated as "not similar."[3] The PEs checked in either of the columns are considered to have overlapping content with NAEP; those checked in the "similar" column are considered to be "aligned." In the 3–5 grade band, the "similar" column includes grade 4 PEs grouped with NAEP grade 4 objectives and rated as similar by the expert panel. In addition, alternative PEs in grades 3 and 5 that were identified by the panel as covering content included in NAEP at grade 4 are denoted in parentheses.

- **Grouped with NAEP TEL**: The next pair of columns in each exhibit includes checkboxes to indicate which NGSS PEs were grouped with NAEP TEL objectives that cover related content at the corresponding grade level. These include PEs in engineering design as well as a subset of the PEs in the sciences with connections to engineering, technology, and applications of science (ETS). As described above for PEs grouped with NAEP science, each PE is indicated as "similar" or "not similar" for content based on the expert panel ratings.

- **Not grouped with NAEP**: The last column in each exhibit includes checkboxes to indicate which NGSS PEs were not grouped with any NAEP content objectives at the corresponding grade level in either the science or TEL frameworks.

---

[2] The full text of each NGSS performance expectation can be found online on the NGSS website: http://www.nextgenscience.org/search-performance-expectations?

[3] The "not similar" category in appendix B reflects the expert panel ratings only for grouped PEs. In contrast, the reporting category of "not similar" in tables 3 and 4 in the Results section of this report reflects both grouped PEs that were rated as "not similar" as well as PEs that were not grouped with NAEP objectives (described in the final bullet below).

Exhibit B-1. NGSS performance expectations (PEs) in the 3–5 grade band compared to the NAEP science and TEL assessment frameworks at grade 4

Disciplinary core ideas in each content domain	NGSS PEs	Grouped with NAEP science[1]		Grouped with NAEP TEL[2]		Not grouped with NAEP
		Similar	Not similar	Similar	Not similar	
Physical sciences						
PS1: Matter and its interactions	5-PS1-3	(✓)				
	5-PS1-4	(✓)				
PS2: Motion and stability: Forces and interactions	3-PS2-1	(✓)				
	3-PS2-3	(✓)				
	5-PS2-1	(✓)				
PS3: Energy	4-PS3-1					✓
	4-PS3-2	✓				
	4-PS3-3					✓
	4-PS3-4	✓		✓		
PS4: Waves and their applications in technologies for information transfer	4-PS4-1		✓			
	4-PS4-2		✓			
	4-PS4-3			✓		
Life sciences						
LS1: From molecules to organisms: Structures and processes	3-LS1-1	(✓)				
	4-LS1-1	✓				
	4-LS1-2					✓
LS2: Ecosystems: Interactions, energy, and dynamics	5-LS2-1	(✓)				
LS3: Heredity: Inheritance and variation of traits	*None* [3]					
LS4: Biological evolution: Unity and diversity	3-LS4-2	(✓)				
	3-LS4-3	(✓)				
	3-LS4-4	(✓)				
Earth and space sciences						
ESS1: Earth's place in the universe	4-ESS1-1		✓			
ESS2: Earth's systems	3-ESS2-1	(✓)				
	4-ESS2-1	✓				
	4-ESS2-2					✓
ESS3: Earth and human activity	4-ESS3-1	✓			✓	
	4-ESS3-2		✓	✓		
	5-ESS3-1	(✓)				
Engineering design						
ETS1: Engineering design	3-5-ETS1-1	†	†	✓		
	3-5-ETS1-2	†	†	✓		
	3-5-ETS1-3	†	†	✓		

† Not applicable.

[1] Includes NGSS performance expectations (PEs) in the physical, life, and Earth and space sciences that were compared with content statements in the NAEP science framework at grade 4. "Similar" includes groupings of grade 4 PEs rated as similar by the expert panel. In addition, alternative PEs in grades 3 and 5 identified by the panel as covering content included in NAEP at grade 4 are denoted in parentheses. Engineering design PEs were not compared with the NAEP science framework since they do not specify science content.

[2] Includes NGSS PEs in engineering design and those in the sciences with connections to engineering, technology, and applications of science that were compared to assessment targets in the NAEP TEL framework at grade 4.

[3] LS3 includes PEs at grade 3, but not grade 4. The panel did not identify alternative grade 3 PEs in LS3 aligned with NAEP grade 4, but related content is covered in 3-LS4-2.

Exhibit B-2. NGSS performance expectations (PEs) in the middle school grade band compared to the NAEP science and TEL assessment frameworks at grade 8

Disciplinary core ideas in each content domain	NGSS PEs	Grouped with NAEP science[1]		Grouped with NAEP TEL[2]		Not grouped with NAEP
		Similar	Not similar	Similar	Not similar	
Physical sciences						
PS1: Matter and its interactions	MS-PS1-1		✓			
	MS-PS1-2	✓				
	MS-PS1-3				✓	
	MS-PS1-4	✓				
	MS-PS1-5	✓				
	MS-PS1-6			✓		
PS2: Motion and stability: Forces and interactions	MS-PS2-1			✓		
	MS-PS2-2	✓				
	MS-PS2-3					✓
	MS-PS2-4	✓				
	MS-PS2-5		✓			
PS3: Energy	MS-PS3-1		✓			
	MS-PS3-2	✓				
	MS-PS3-3	✓		✓		
	MS-PS3-4		✓			
	MS-PS3-5	✓				
PS4: Waves and their applications in technologies for information transfer	MS-PS4-1		✓			
	MS-PS4-2		✓			
	MS-PS4-3					✓
Life Sciences						
LS1: From molecules to organisms: Structures and processes	MS-LS1-1	✓				
	MS-LS1-2		✓			
	MS-LS1-3	✓				
	MS-LS1-4	✓				
	MS-LS1-5	✓				
	MS-LS1-6	✓				
	MS-LS1-7		✓			
	MS-LS1-8					✓
LS2: Ecosystems: Interactions, energy, and dynamics	MS-LS2-1	✓				
	MS-LS2-2	✓				
	MS-LS2-3		✓			
	MS-LS2-4	✓				
	MS-LS2-5		✓	✓		
LS3: Heredity: Inheritance and variation of traits	MS-LS3-1					✓
	MS-LS3-2		✓			
LS4: Biological evolution: Unity and diversity	MS-LS4-1		✓			
	MS-LS4-2	✓				
	MS-LS4-3		✓			
	MS-LS4-4		✓			
	MS-LS4-5				✓	
	MS-LS4-6	✓				

Exhibit B-2. NGSS performance expectations (PEs) in the middle school grade band compared to the NAEP science and TEL assessment frameworks at grade 8—Continued

Disciplinary core ideas in each content domain	NGSS PEs	Grouped with NAEP science[1]		Grouped with NAEP TEL[2]		Not grouped with NAEP
		Similar	Not similar	Similar	Not similar	
Earth and Space Sciences						
ESS1: Earth's place in the universe	MS-ESS1-1	✓				
	MS-ESS1-2	✓				
	MS-ESS1-3		✓			
	MS-ESS1-4	✓				
ESS2: Earth's systems	MS-ESS2-1		✓			
	MS-ESS2-2	✓				
	MS-ESS2-3	✓				
	MS-ESS2-4		✓			
	MS-ESS2-5	✓				
	MS-ESS2-6	✓				
ESS3: Earth and human activity	MS-ESS3-1					✓
	MS-ESS3-2		✓			
	MS-ESS3-3	✓		✓		
	MS-ESS3-4		✓			
	MS-ESS3-5		✓			
Engineering Design						
ETS1: Engineering design	MS-ETS1-1	†	†	✓		
	MS-ETS1-2	†	†	✓		
	MS-ETS1-3	†	†		✓	
	MS-ETS1-4	†	†	✓		

† Not applicable.

[1] Includes NGSS performance expectations in the physical, life, and Earth and space sciences that were compared with content statements in the NAEP science framework at grade 8. Engineering design PEs were not compared with the NAEP science framework since they do not specify science content.

[2] Includes NGSS performance expectations in engineering design and those in the sciences with connections to engineering, technology, and applications of science that were compared with assessment targets in the NAEP TEL framework at grade 8.

Exhibit B-3. NGSS performance expectations (PEs) in the high school grade band compared to the NAEP science and TEL assessment frameworks at grade 12

Disciplinary core ideas in each content domain	NGSS PEs	Grouped with NAEP science[1]		Grouped with NAEP TEL[2]		Not grouped with NAEP
		Similar	Not similar	Similar	Not similar	
Physical Sciences						
PS1: Matter and its interactions	HS-PS1-1	✓				
	HS-PS1-2	✓				
	HS-PS1-3	✓				
	HS-PS1-4		✓			
	HS-PS1-5					✓
	HS-PS1-6				✓	
	HS-PS1-7					✓
	HS-PS1-8	✓				
PS2: Motion and stability: Forces and interactions	HS-PS2-1	✓				
	HS-PS2-2	✓				
	HS-PS2-3	✓			✓	
	HS-PS2-4	✓				
	HS-PS2-5					✓
	HS-PS2-6		✓			
PS3: Energy	HS-PS3-1		✓			
	HS-PS3-2	✓				
	HS-PS3-3		✓	✓		
	HS-PS3-4		✓			
	HS-PS3-5		✓			
PS4: Waves and their applications in technologies for information transfer	HS-PS4-1	✓				
	HS-PS4-2				✓	
	HS-PS4-3		✓			
	HS-PS4-4		✓			
	HS-PS4-5					✓
Life Sciences						
LS1: From molecules to organisms: Structures and processes	HS-LS1-1	✓				
	HS-LS1-2					✓
	HS-LS1-3					✓
	HS-LS1-4		✓			
	HS-LS1-5	✓				
	HS-LS1-6	✓				
	HS-LS1-7		✓			
LS2: Ecosystems: Interactions, energy, and dynamics	HS-LS2-1		✓			
	HS-LS2-2	✓				
	HS-LS2-3		✓			
	HS-LS2-4	✓				
	HS-LS2-5		✓			
	HS-LS2-6	✓				
	HS-LS2-7		✓	✓		
	HS-LS2-8					✓

Exhibit B-3. NGSS performance expectations (PEs) in the high school grade band compared to the NAEP science and TEL assessment frameworks at grade 12—Continued

Disciplinary core ideas in each content domain	NGSS PEs	Grouped with NAEP science[1]		Grouped with NAEP TEL[2]		Not grouped with NAEP
		Similar	Not similar	Similar	Not similar	
LS3: Heredity: Inheritance and variation of traits	HS-LS3-1	✓				
	HS-LS3-2		✓			
	HS-LS3-3	✓				
LS4: Biological evolution: Unity and diversity	HS-LS4-1	✓				
	HS-LS4-2	✓				
	HS-LS4-3	✓				
	HS-LS4-4	✓				
	HS-LS4-5	✓				
	HS-LS4-6		✓	✓		
Earth and space sciences						
ESS1: Earth's place in the universe	HS-ESS1-1	✓				
	HS-ESS1-2	✓				
	HS-ESS1-3	✓				
	HS-ESS1-4		✓			
	HS-ESS1-5	✓				
	HS-ESS1-6	✓				
ESS2: Earth's systems	HS-ESS2-1	✓				
	HS-ESS2-2		✓			
	HS-ESS2-3		✓			
	HS-ESS2-4	✓				
	HS-ESS2-5		✓			
	HS-ESS2-6	✓				
	HS-ESS2-7		✓			
ESS3: Earth and human activity	HS-ESS3-1		✓			
	HS-ESS3-2			✓		
	HS-ESS3-3			✓		
	HS-ESS3-4		✓	✓		
	HS-ESS3-5		✓			
	HS-ESS3-6		✓			
Engineering design						
ETS1: Engineering design	HS-ETS1-1	†	†	✓		
	HS-ETS1-2	†	†		✓	
	HS-ETS1-3	†	†	✓		
	HS-ETS1-4	†	†	✓		

† Not applicable.

[1] Includes NGSS performance expectations in the physical, life, and Earth and space sciences that were compared with content statements in the NAEP science framework at grade 12. Engineering design PEs were not compared with the NAEP science framework since they do not specify science content.

[2] Includes NGSS performance expectations in engineering design and those in the sciences with connections to engineering, technology, and applications of science that were compared with assessment targets in the NAEP TEL framework at grade 12.