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

Technical Report

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1. Introduction

New national standards documents have been developed over the past few years in the areas of science, technology, engineering, and mathematics (STEM) and are leading to major changes in state curricula and assessments. The most recent of these documents is the *Next Generation Science Standards* (NGSS Lead States 2013).[1] The NGSS are based on a vision for science education first described in *A Framework for K-12 Science Education* (National Research Council [NRC], 2012)—referred to throughout the report as the K-12 Frameworks—and they elaborate for each grade level a set of concrete student outcomes, or performance expectations, based on the K-12 Framework that describe what *all* students should know and be able to do in science and engineering across the grades. The NGSS and the K-12 Framework are based on three dimensions: (1) disciplinary core ideas (within four content domains) that reflect a coherent progression of student knowledge across grades; (2) scientific and engineering practices (including mathematics-related practices) that describe what students should be able to do with their science knowledge; and (3) cross-cutting concepts that unify the study of science and engineering. Together the NGSS and the K-12 Framework are intended to inform curriculum development, instruction, professional development, and student assessment.[2]

Alongside these new initiatives are the existing national assessments of STEM subjects provided by the National Assessment of Educational Progress (NAEP). NAEP is the congressionally mandated assessment program that is regularly conducted to report on what students across the United States know and can do in a variety of subject areas and across a range of proficiency levels at specific stages of their K-12 schooling. Relevant to this study, NAEP assesses students at grades 4, 8, and 12 in science and mathematics to report trends in achievement since the early 1990s. In addition, in 2014 the first NAEP assessment in technology and engineering literacy (TEL) was conducted at grade 8.

Each NAEP assessment is based on an assessment framework. Like the NGSS, the NAEP assessment frameworks include a content dimension with grade-specific content objectives that describe what is to be assessed at each grade level. They also include a cognitive dimension describing how students are expected to apply their content knowledge; for the science and TEL frameworks this dimension (like the NGSS) is described in terms of science practices and technology and engineering practices, respectively.[3]

Knowing how the NGSS relate to the three NAEP assessment frameworks for STEM subjects—science, TEL, and mathematics—is important for policymakers, researchers, educators, and the public. Thus, the National Center for Education Statistics (NCES) commissioned this study to inform ongoing

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

[2] 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 *Guide to Implementing the Next Generation Science Standards* (NRC 2015).

[3] The NGSS and NAEP frameworks are further described in section 2 of this report.

discussions of the role of NAEP in relation to emerging national systems of assessments in STEM subjects.[4]

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

1.1 Benefits and Limitations of the Study

There are multiple benefits to be gained from a comparison of the NGSS with the NAEP STEM frameworks. For the science comparisons, similarities suggest areas where NAEP may provide useful science assessment examples and national achievement data on the student understandings in the natural sciences described in the NGSS. Differences suggest areas where NAEP and NGSS-based science assessments may each provide unique contributions. The TEL comparisons augment these findings by identifying additional areas of overlap with the engineering and technology content and practices in the 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 the performance expectations in science and engineering do not specify explicit mathematics requirements. However, the mathematics students may need to use in responding to items developed to assess these performance expectations can be inferred and compared to the mathematics included in NAEP across grades. Thus, such comparisons can provide information on how assessments based on the NGSS might compare with NAEP in terms of the level of mathematics and quantitative skills that would be required of students.

The results of the study are important for NAEP as NCES continues to explore new approaches, including recommendations from the Future of NAEP summit[5] such as incremental updates to assessment frameworks; expansion of NAEP item pools to cover content from the Common Core State Standards for Mathematics (CCSS-M) (and the NGSS by extension); and changes to the design of NAEP STEM assessments (Haertel et al. 2012). The results of the study may also be helpful to states as they move forward with implementing the NGSS and developing new assessments and for understanding differences between results from NAEP and NGSS-based assessments.

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[4] A prior study conducted by the NAEP Validity Studies (NVS) Panel examined the alignment of the NAEP mathematics framework with the *Common Core State Standards for Mathematics* (Hughes et al. 2013)

[5] NCES convened a diverse group of experts in assessment, measurement, cognition, and technology for the first Future of NAEP summit in August 2011, and state and local stakeholders for the second summit in January 2012. These meetings resulted in a white paper, written by a panel of participants from both summits, that provides recommendations on the role of NAEP.

There are also 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 framework objectives, 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. Item-level comparisons were not conducted as part of this study since the most recent NAEP mathematics and science assessment items—2015—were not yet available at the time of the study and because NGSS-based assessments are still under development.

1.2 Research Questions

Three research questions guide this 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)?

1.3 Organization of the Report

Following this introductory section, the report is organized as follows:

- *Section 2. Overview of the NGSS and NAEP STEM Frameworks* provides an overview and comparison of the documents that were reviewed for this study.

- *Section 3. Study Design and Methods* describes the study design and related considerations, as well as the data collection and analysis methods used for the comparisons. The methods used for the science and TEL comparisons are described separately from the methods used for the more limited mathematics comparisons.

- *Section 4. Results* describes the results of the study, drawing on the quantitative and qualitative data collected. It presents results from the science comparisons, the TEL comparisons, science and TEL combined, and the mathematics comparisons.
- *Section 5. Summary and Conclusions* summarizes the main findings from the science, TEL, and mathematics comparisons.

Appendices A to G provide additional detail on background, methods, and results.

2. Overview of the NGSS and NAEP STEM Frameworks

Five documents were reviewed for this framework comparison study:

- *A Framework for K-12 Science Education* (NRC 2012)*;*
- *Next Generation Science Standards* (NGSS Lead States 2013);
- *Science Framework for the 2015 National Assessment of Educational Progress* ((NAGB 2014b);
- *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress* (NAGB 2013b); and
- *Mathematics Framework for the 2015 National Assessment of Educational Progress* (NAGB 2014b).

This section describes the purpose and the structure of these documents and provides a brief comparison of their dimensions.

2.1 Purpose of the NGSS and NAEP STEM Frameworks

The documents reviewed for the study have purposes that are not strictly parallel. Each of these documents is described in turn below, with notes on their development provided in the textbox at the end of this section.

The purpose of *A Framework for K-12 Science Education* is to present a broad conceptual framework, or vision, for the future of science education in the United States. It is a foundational document intended to inform curricula, pedagogy, assessments, and professional development; it is a "first step in [the] process to create new standards in K-12 science education" (NRC 2012, p. ix). In doing so, it aims to bring more coherence, systematicity, depth, and real-world grounding to science education such that, at the end of their secondary education, students will be aptly prepared for the science-related aspects of their individual lives and today's world, and those with interest in science careers will have a solid foundation for further study in college. The K-12 Framework was included in the document reviews because it is the foundational document for the NGSS, but it is not the focus of the study's comparisons.

The purpose of the *Next Generation Science Standards* is to elaborate for each grade a set of concrete student outcomes (performance expectations) for science education based on the K-12 Framework that describe what *all* students should know and be able to do in science and engineering across the grades. However, the NGSS do not go so far as to describe how these performance expectations should be assessed, which instead will be a job for the states as they create assessment guidelines aligned with the NGSS.

The purpose of the NAEP science, TEL, and mathematics frameworks, in contrast, is explicitly to guide the development of the NAEP assessments at grades 4, 8, and 12, which assess a full range of

proficiency levels. The frameworks describe in detail the content and cognitive dimensions to be covered, identify the target percentage of the assessments that should be devoted to the main categories within each framework dimension at each grade level, and describe the types of items and tasks to be included in the assessments.[6] While the NGSS also ultimately inform the development of assessments (by describing student performance expectations across grades), they do not include directives regarding the target percentage of assessments to be devoted to the various dimensions like the NAEP frameworks. Nor do the NGSS address item and task formats, since they are standards and not assessment guidelines. Additional guidelines on assessing the NGSS, rather, are provided in a recent separate publication (NRC 2014). The NGSS, together with the K-12 framework, are intended to inform not just assessments but curricula, instruction, and professional development as well.

Comparisons of these documents are informative despite their differences. The boundaries for science education described in the K-12 Framework and the performance expectations elaborated in the NGSS can be compared to the boundaries of the NAEP science and TEL frameworks to determine what is overlapping and what is unique. The mathematics involved in the NGSS performance expectations can also be compared to the mathematics included in the NAEP mathematics framework across grades.

Development of the K-12 Framework, NGSS, and NAEP STEM Frameworks

The development of the **K-12 Framework** was undertaken by the National Academy of Sciences' National Research Council with funding from the Carnegie Corporation. A team of 18 nationally and internationally known experts (including practicing scientists, Nobel laureates, cognitive scientists, science education researchers, and science education standards and policy experts) drafted the document, which draws on research on teaching and learning in science and prior efforts to define the parameters of K-12 science education.

The **NGSS** were developed by teams from 26 states who, under the coordination of Achieve, Inc., worked collaboratively with other stakeholders in science, science education, higher education, and industry to elaborate the grade-specific performance expectations based on the K-12 Framework.

The **NAEP assessment frameworks** are developed under the auspices of the National Assessment Government Board. Each framework is developed by two committees—a steering committee and a planning committee—including leaders in education and assessment as well as subject matter experts and teachers. The committee members draw across U.S. curricula and the best thinking and research of wide-ranging experts from government, education, business, and the public sector. While national standards and curriculum documents inform the development of NAEP frameworks, NAEP produces independent assessment frameworks that are not guided by any single source. The NAEP science and TEL assessment frameworks were developed prior to the K-12 Framework and were direct antecedents that informed multiple aspects of the K-12 Framework and the NGSS.

2.2 Structure of the NGSS and NAEP STEM Frameworks

The NGSS and NAEP framework documents reviewed for this study have both similarities and differences in their organization and structures, which reflect their individual purposes. The similarities

[6] In addition to the assessment frameworks, NAEP also has assessment specifications documents that provide further guidance for the development of assessments for each subject and that were consulted for the study (NAGB 2007a; NAGB 2007b; NAGB 2013a).

among the documents are that they each have two major dimensions—identifying the key content knowledge and the key cognitive skills or practices that students should acquire and demonstrate—and they span the range of education from elementary to high school (see exhibit 1). An important distinction, however, is that the K-12 Framework and the NGSS are comprehensive across the grades (given their purpose to elaborate a vision and standards for K-12 science education), whereas the NAEP frameworks describe what students should know and be able to do at specific points in their school careers—grades 4, 8, and 12—although they typically reflect some knowledge and skills acquired in earlier grades, as well.

Exhibit 1. Overview of the K-12 framework, NGSS, and NAEP STEM frameworks

Framework/Standards Document	Organizing Dimensions (Content and Cognitive)	Grade Level Expectations		
		Elementary School	Middle School	High School
Framework for K-12 Science Education	Disciplinary Core Ideas (DCIs) in four content domains Physical Sciences; Life Sciences; Earth and Space Sciences; Engineering, Technology, and Applications of Science Scientific and Engineering Practices Crosscutting Concepts	**Content expectations for the DCIs at endpoints for …**		
		Grade bands K-2 and 3-5	Grade band 6-8	Grade band 9-12
Next Generation Science Standards (NGSS)	Disciplinary Core Ideas (DCIs) in four content domains Physical Sciences; Life Sciences; Earth and Space Sciences; Engineering, Technology, and Applications of Science Scientific and Engineering Practices Crosscutting Concepts	**Performance expectations that *integrate* the DCIs, scientific and engineering practices, and crosscutting concepts for …**		
		Each of grades K-5[1]	Grade band 6-8	Grade band 9-12
NAEP Science Framework	Content Areas Physical Science; Life Science; Earth and Space Sciences Science Practices	**Content statements for …**[2]		
		Grade 4	Grade 8	Grade 12
NAEP Technology and Engineering Literacy (TEL) Framework	Assessment Areas Design and Systems; Technology and Society; Information and Communication Technology TEL Practices	**Assessment targets for …**[2]		
		Grade 4	Grade 8	Grade 12
NAEP Mathematics Framework	Content Areas Number Properties and Operations; Measurement; Geometry; Data Analysis, Statistics, and Probability; Algebra Mathematical Complexity Level (low, moderate, high)	**Objectives for …**[2]		
		Grade 4	Grade 8	Grade 12

[1] The NGSS include performance expectations for the three natural science disciplines (physical, life, and Earth and space science) and for engineering design. Performance expectations in elementary school are included at each of grades K-5 in the science disciplines; for engineering design, performance expectations are provided at the endpoints for two elementary grade bands (K-2 and 3-5).

[2] The NAEP frameworks do not provide grade-level specifications for the cognitive dimensions (practices in science and TEL and mathematical complexity in mathematics), which cut across all content areas and grades. In NAEP, grade-specific content objectives are integrated with the cognitive dimension at the stage of assessment item development.

SOURCE: National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, 2012. Next Generation Science Standards Lead States, *Next Generation Science Standards: For States, By States*, 2013. National Assessment Governing Board, *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress*, 2013. National Assessment Governing Board, *Mathematics Framework for the 2015 National Assessment of Educational Progress*, 2014. National Assessment Governing Board *Science Framework for the 2015 National Assessment of Educational Progress*, 2014.

2.2.1 The NGSS and K-12 Framework

The NGSS are based on the organizational dimensions described in the K-12 Framework, which were developed to reflect a vision of science education in the United States "in which students … actively engage in scientific and engineering practices and apply crosscutting concepts to deepen their understanding of core ideas in these fields" (NRC 2012, p. 8). As such, the three dimensions specified in the K-12 Framework upon which the NGSS are built are: disciplinary core ideas (within four content domains), scientific and engineering practices, and crosscutting concepts (see exhibit 2).

The content domains organizing the disciplinary core ideas are physical sciences, life sciences, and Earth and space sciences (in the natural sciences); and engineering, technology, and applications of science (ETS). Engineering and technology are included along with the natural sciences in order to reflect the importance of the human-built world and to recognize the value of better integrating the two domains.

In the K-12 Framework, each disciplinary core idea is further broken down into a set of component ideas, each with broad content expectations for grade bands ending at grades 2, 5, 8, and 12.[7] The eight scientific and engineering practices elaborate the processes and habits of science and scientific thinking and include: *asking questions and defining problems*; *developing and using models*; *planning and carrying out investigations*; *analyzing and interpreting data*; *constructing explanations and designing solutions*; *engaging in argument from evidence*; and *obtaining, evaluating, and communicating information*. The seven crosscutting concepts are those concepts that bridge the different content areas, connections which students should understand to have a coherent and scientifically-based view of the world. These include: *patterns*; *cause and effect*; *scale, proportion, and quantity*; *systems and system models*; *energy and matter*; *structure and function*; and *stability and change*.

[7] The full list of component ideas for each disciplinary core idea is shown in Appendix B (exhibit B-1 and exhibit B-3).

Exhibit 2. Overview of the NGSS (and K-12 framework) dimensions

Dimensions	Description
Disciplinary core ideas in content domains[1]	Physical Sciences (PS) PS1: Matter and its interactions PS2: Motion and stability: forces and interactions PS3: Energy PS4: Waves and their applications in technologies for information transfer Life Sciences (LS) LS1: From molecules to organisms: structures and processes LS2: Ecosystems: interactions, energy, and dynamics LS3: Heredity: inheritance and variation of traits LS4: Biological evolution: unity and diversity Earth and Space Sciences (ESS) ESS1: Earth's place in the universe ESS2: Earth's systems ESS3: Earth and human activity Engineering, Technology, and Applications of Science (ETS) ETS1: Engineering design ETS2: Links among engineering, technology, science, and society
Scientific and engineering practices[2]	1. Asking questions (science) and defining problems (engineering) 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing explanations (science) and designing solutions (engineering) 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information
Crosscutting concepts	1. Patterns 2. Cause and effect: mechanism and explanation 3. Scale, proportion, and quantity 4. System and system models 5. Energy and matter: flows, cycles, and conservation 6. Structure and function 7. Stability and change

[1] Content domains are denoted by an abbreviation in capital letters (PS, LS, ESS, and ETS). Each of the disciplinary core ideas (DCI) within a content domain is denoted with an Arabic numeral (e.g., there are four DCI's specified in the domain of physical sciences). Each disciplinary core idea is further broken down into component ideas and denoted again with a capital letter (not shown). For example, PS1.A for "structure and properties of matter" and PS1.B for "chemical reactions" are two component ideas within the same disciplinary core idea (PS1). The full list of component ideas for each disciplinary core idea is shown in exhibits B-1 and B-3 of appendix B.

[2] Practices 1 and 6 indicate that one part of these practices is particularly relevant to science and the other part is particularly relevant to engineering. All other practices apply to both science and engineering.

SOURCE: National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, 2012.

The NGSS use the guidance in the K-12 Framework at the grade band endpoints to develop a set of grade-specific performance expectations that *integrate* specific disciplinary core ideas with a primary scientific and engineering practice and require the application of at least one crosscutting concept. For each disciplinary core idea that is applicable at a given grade level, the NGSS articulate one or more performance expectations. Each performance expectation is then referenced to the specific component(s) of a disciplinary core idea, scientific and engineering practice, and crosscutting concept to which it relates.[8] In other words, in the NGSS, there is no content that is described out of the context of scientific and engineering practices and crosscutting concepts — in that way, NGSS performance expectations differ from the grade band expectations described in the K-12 Framework, which are focused only on the science or engineering content represented by the disciplinary core ideas.

The structure of the NGSS differs substantially from the other frameworks discussed here because of the focus on the integration of the three organizing dimensions. Exhibit 3 provides an example of how an NGSS performance expectation table is structured. It shows how each performance expectation has both a content aspect (based on the disciplinary core idea(s) to which it is classified) and a practices aspect (based on a primary scientific and engineering practice). The NGSS also provide additional guidance on the components of the practices for each grade level (see NGSS Lead States 2013, appendix F). For example, in the exhibit, the label 4-LS1-1 identifies the first (of two) performance expectations for the first disciplinary core idea in fourth-grade life science (4-LS1): *Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction*. The scientific and engineering practice to which the performance expectation maps is identified as *engaging in argument from evidence*—as suggested by the phrase "construct an argument …." The component idea to which it maps is LS1.A, which relates to structure and function as described by the remaining text of the performance expectation. In addition, both performance expectations (4-LS1-1 and 4-LS1-2) reflect the crosscutting concept of *systems and system models*. The NGSS also indicate connections between performance expectations involving mathematics-related practices and the Common Core State Standards for Mathematics (CCSS-M). In exhibit 3, performance expectation 4-LS1-1 is connected with a grade 4 CCSS-M standard (4.G.A.3) related to lines of symmetry.

[8] All the disciplinary core ideas are covered in the NGSS in each grade band (i.e., K-2, 3-5, middle school, and high school), but not at every grade in elementary school.

Exhibit 3. Example NGSS performance expectation table

4-LS1 From Molecules to Organisms: Structures and Processes

4-LS1 From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

4-LS1-1. **Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.** [Clarification Statement: Examples of structures could include thorns, stems, roots, colored petals, heart, stomach, lung, brain, and skin.] [Assessment Boundary: Assessment is limited to macroscopic structures within plant and animal systems.]

4-LS1-2. **Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.** [Clarification Statement: Emphasis is on systems of information transfer.] [Assessment Boundary: Assessment does not include the mechanisms by which the brain stores and recalls information or the mechanisms of how sensory receptors function.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.

- Use a model to test interactions concerning the functioning of a natural system. (4-LS1-2)

Engaging in Argument from Evidence

Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).

- Construct an argument with evidence, data, and/or a model. (4-LS1-1)

Disciplinary Core Ideas

LS1.A: Structure and Function

- Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (4-LS1-1)

LS1.D: Information Processing

- Different sense receptors are specialized for particular kinds of information, which may be then processed by the animal's brain. Animals are able to use their perceptions and memories to guide their actions. (4-LS1-2)

Crosscutting Concepts

Systems and System Models

- A system can be described in terms of its components and their interactions. (4-LS1-1),(4-LS1-2)

Connections to other DCIs in fourth grade: N/A

Articulation of DCIs across grade-levels: **1.LS1.A** (4-LS1-1); **1.LS1.D** (4-LS1-2); **3.LS3.B** (4-LS1-1); **MS.LS1.A** (4-LS1-1),(4-LS1-2); **MS.LS1.D** (4-LS1-2)

Common Core State Standards Connections:

ELA/Literacy –

W.4.1 Write opinion pieces on topics or texts, supporting a point of view with reasons and information. (4-LS1-1)

SL.4.5 Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes. *(4-LS1-2)*

Mathematics –

4.G.A.3 Recognize a line of symmetry for a two-dimensional figure as a line across the figure such that the figure can be folded across the line into matching parts. Identify line-symmetric figures and draw lines of symmetry. *(4-LS1-1)*

NOTE: This example shows a performance expectation table from the NGSS. The title and the gray band at the top identify that the performance expectations are related to grade 4 life sciences disciplinary core idea 1: From molecules to organisms (4-LS1). The white box below the gray band identifies the two performance expectations (4-LS1-1 and 4-LS1-2). The blue, orange, and green boxes identify the scientific and engineering practices, the specific component ideas (e.g., LS1.A and LS1.D) within the disciplinary core idea, and the crosscutting concepts on which the performance expectations draw. The white boxes at the bottom show the links to other disciplinary core ideas at the same grade and at other grades and connections to the Common Core State Standards for English language arts (ELA) and mathematics.

SOURCE: Next Generation Science Standards Lead States, *Next Generation Science Standards: For States, By States*, 2013, p. 38.

The NGSS provide a set of performance expectations for each of the four content domains (three covering the natural sciences and the fourth covering ETS). In the natural sciences, performance expectations are provided for each grade in elementary school (K-5) and for the middle school and high school grade bands. The fourth content domain, ETS, is covered by two types of performance expectations: a set in engineering design for four grade bands (K-2, 3-5, middle school, and high school) and a portion of those in the natural sciences that have explicit connections to ETS.

A notable feature of the NGSS is the focus on applying science knowledge. For the performance expectations in the science disciplines with connections to ETS, the connection to science content is specified because the performance expectations are classified to disciplinary ideas in both the sciences and ETS. The performance expectations in engineering design, while not specifying particular science content, presumably could be applied in numerous science contexts based on the disciplinary core ideas at each grade level.

For example, an NGSS performance expectation in engineering design for high school (HS-ETS1-1) states: "*Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants*." The type of global challenge is not specified, and this performance expectation may be set in a number of contexts, such as global climate change or sustainable energy sources when assessed. In contrast, an NGSS performance expectation in life sciences with connections to ETS **(**HS-LS2-7) states: "*Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity*," which is explicit about the science required.

2.2.2 NAEP science framework

The NAEP science framework includes separate content and cognitive dimensions that together describe what students should know and be able to do (see table 1). The science content 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 for grades 4, 8, and 12.[9] For example, within the topic of "matter" in physical science, there is a subtopic "properties of matter" and multiple content statements relating to it at each grade (e.g., content statement P4.01, for grade 4, states: "*Objects and substances have properties. Weight (mass) and volume are properties that can be measured using appropriate tools*."). In terms of target assessment time, NAEP science is evenly distributed across the content areas at grade 4, has a slightly higher emphasis on Earth and space sciences (40 percent) than physical or life sciences (30 percent each) at grade 8, and has a slightly lower emphasis on Earth and space sciences (25 percent) than physical or life sciences (37.5 percent each) at grade 12.

[9] See exhibit B-1 in appendix B for the full list of NAEP science topics and subtopics by content area.

The cognitive dimension includes four broad science practices that describe the ways in which students should be able to use the science principles reflected in the content dimension and that are associated with a range of cognitive demands:[10]

1) *Identifying science principles*, which focuses on students' ability to recognize, recall, define, relate, and represent basic science principles specified in the content statements, or knowing "that" (declarative knowledge);
2) *Using science principles*, which focuses on what makes science knowledge valuable (i.e., making accurate predictions about phenomena and explaining observations of the natural world), or knowing "why" (schematic knowledge);
3) *Using scientific inquiry*, which involves applying science knowledge and inquiry skills to design and conduct investigations and draw conclusions based on evidence, or knowing "how" (procedural knowledge); and
4) *Using technological design*, which involves the systematic process of applying science knowledge and design skills to solve problems in a real-world context, or "knowing when and where to apply knowledge" (strategic knowledge).

The target percentage of assessment time across the science practices indicates an increase in emphasis on *using science principles* (from 30 to 40 percent) and a decrease in emphasis on *identifying science principles* (from 30 to 20 percent) across grades 4, 8, and 12. The target percentages in *using scientific inquiry* (30 percent) and *using technological design* (10 percent) are the same at all three grades.

[10] The four practices are not considered to be purely distinct, but rather as having some overlap.

Table 1. NAEP science framework dimensions and target percentages of assessment time, by grade

NAEP science framework dimensions	Framework target percentages[1]		
	Grade 4	Grade 8	Grade 12
Science content areas (and topics)			
Physical science	33.3	30.0	37.5
Matter	†	†	†
Energy	†	†	†
Motion	†	†	†
Life science	33.3	30.0	37.5
Structures and functions of living systems	†	†	†
Changes in living systems	†	†	†
Earth and space sciences	33.3	40.0	25.0
Earth in space and time	†	†	†
Earth structures	†	†	†
Earth systems	†	†	†
Science practices			
Identifying science principles	30	25	20
Using science principles	30	35	40
Using scientific inquiry	30	30	30
Using technological design	10	10	10

† Not applicable. Framework target percentages are provided at the content area level, but not at the topic level.

[1] Framework target percentages reflect the percentage of assessment time to be devoted to each content area and science practice.

NOTE: This table displays the two dimensions of the NAEP science framework (content areas and science practices) along with the target percentages of assessment time specified for each content area and science practice at grades 4, 8, and 12. Each content area is broken down into topics, which are listed in the table. Each of the topics within the three content areas is further broken down into subtopics (see exhibit B-1) and grade-specific content statements (not shown).

SOURCE: National Assessment Governing Board, *Science Framework for the 2015 National Assessment of Educational Progress*, 2014.

The NAEP science framework illustrates how any content statement and any science practice can be combined into a grade-specific performance expectation for the development of assessment items. For example, the grade 8 content statement "*properties of solids, liquids, and gases are explained by a model of matter that is composed of tiny particles in motion*" may be combined with the practice of *identifying science principles* to generate a performance expectation such as "*given an animation of molecules in motion, identify the substance that is being illustrated as a solid, liquid, or gas*." However, the NAEP framework does not specify *particular* combinations that must be assessed at each grade as the integrated NGSS performance expectations do. Instead, NAEP assessment developers integrate the two dimensions of the framework to produce a broad range of performance expectations and then develop items and tasks at each grade level that assess both content and practices. This less restrictive approach allows NAEP to meet its mission to assess student achievement across a range of proficiency levels. In contrast, the more restrictive approach of the NGSS allows for more precision in terms of specific performance standards within and across grades and is consistent with its goals to identify standards that all students should meet.

The NAEP science framework also emphasizes the importance of "crosscutting content"—such as matter and energy conservation and transformation, and biogeochemical cycles—which draws on key science principles from across the three content areas. However, crosscutting content is treated differently in NAEP than it is in the NGSS. In the K-12 Framework and the NGSS, "crosscutting

concepts" connecting the science disciplines are treated as a third dimension (in addition to disciplinary core ideas and scientific and engineering practices). In the NAEP framework, rather than being treated as a separate dimension, crosscutting content is reflected in specific content statements across the physical, life, and Earth and space sciences.[11]

Finally, the NAEP science framework calls for a portion of the assessment to include interactive computer-based tasks and hands-on performance tasks. There are four types of interactive computer tasks specified in the framework: information search and analysis, empirical investigation, simulation of phenomena and models, and concept mapping. The hands-on performance tasks require students to work with physical equipment and materials to conduct scientific investigations. These two types of assessment formats provide for a deeper measure of students' understanding of science principles and their ability to fully engage in the science practices than do traditional individual assessment item formats, which are also included in the NAEP science assessment.

2.2.3 NAEP TEL framework

The NAEP TEL framework, like the science framework, includes separate content and cognitive dimensions that together describe what students should know and be able to do (see table 2). The TEL framework specifies three assessment areas—design and systems, technology and society, and information and communication technology (ICT)—each of which is further broken down into subareas, for which there are a set of grade-specific assessment targets at grades 4, 8, and 12 that describe what students should either know or be able to do. For example, within the subarea of "Interaction of Technology and Humans" in Technology and Society, there are multiple assessment targets at each grade. At grade 4, one of these assessment targets, T.04.01, states that "Students know that: People's needs and desires determine which new tools, products, and machines are developed and made available." At grade 8, one of these assessment targets, T.08.03, states that "Students are able to: Describe and analyze positive and negative impacts on society from the introduction of a new or improved technology, including both expected and unanticipated effects."

In NAEP TEL, the target distribution of assessment time across the three assessment areas in the framework indicates the greatest emphasis on ICT (45 percent) at grade 4 and on design and systems (40 percent) at grade 8. The emphasis at grade 12 is more evenly distributed across the assessment areas, with 35 percent each in design and systems and ICT and 30 percent in technology and society.

The cognitive dimension includes three overlapping engineering and technology practices that articulate the types of thinking and reasoning required of students:

- *Understanding technological principles*, which focuses on students' knowledge and understanding of technology and their capacity to think and reason with that knowledge;

[11] Further descriptions of crosscutting content and how it provides opportunities for greater depth of assessment of key science principles across content areas are included in the NAEP specifications document (NAGB 2007b). Looking at the topics and subtopics in the NAEP content areas (see exhibit B-1), it is clear that there is some overlap with the crosscutting concepts in the NGSS.

- *Developing solutions and achieving goals*, which relates to students' systematic application of technological knowledge, tools, and skills to address problems and achieve goals presented in societal, design, curriculum, and realistic contexts; and
- *Communicating and collaborating*, which relates to students' capabilities to use contemporary technologies to communicate for a variety of purposes and in a variety of ways, individually or in teams (generated virtually).

The target percentage of assessment time across the TEL practices is the same at grades 4, 8, and 12 (30 percent in understanding technological principles, 40 percent in developing solutions and achieving goals, and 30 percent in communicating and collaborating).

Table 2. NAEP technology and engineering literacy (TEL) framework dimensions and target percentages of assessment time, by grade

NAEP TEL framework dimensions	Framework target percentages[1]		
	Grade 4	Grade 8	Grade 12
TEL assessment areas (and subareas)			
Design and Systems	30	40	35
Nature of technology	†	†	†
Engineering design	†	†	†
Systems thinking	†	†	†
Maintenance and troubleshooting	†	†	†
Technology and Society	25	25	30
Interaction of technology and humans	†	†	†
Effects of technology on the natural world	†	†	†
Effects of technology on the world of information and knowledge	†	†	†
Ethics, equity, and responsibility	†	†	†
Information and Communication Technology (ICT)	45	35	35
Construction and exchange of ideas and solutions	†	†	†
Information research	†	†	†
Investigation of problems	†	†	†
Acknowledgment of ideas and information	†	†	†
Selection and use of digital tools	†	†	†
TEL Practices			
Understanding technological principles	30	30	30
Developing solutions and achieving goals	40	40	40
Communicating and collaborating	30	30	30

† Not applicable. Framework target percentages are provided at the assessment area level, but not at the subarea level.

[1] Framework target percentages reflect the percentage of assessment time to be devoted to each assessment area and TEL practice.

NOTE: This table displays the two dimensions of the NAEP TEL framework (assessment areas and TEL practices) along with the target percentages of assessment time specified for each assessment area and practice at grades 4, 8, and 12. Each assessment area is broken down into subareas, which are listed in the table. Each of the subareas within the three assessment areas is further broken down into grade-specific assessment targets (not shown).

SOURCE: National Assessment Governing Board, *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress*, 2013.

As in science, the technology and engineering practices can be combined with any assessment target to develop a grade-specific performance expectation, but the particular combinations that must be assessed are not specified in the NAEP TEL framework as they are in the NGSS. Another notable

distinction from the NGSS is that TEL performance expectations (and related tasks) do not require students to apply their knowledge of science, because prior science content knowledge is not expected or assessed in NAEP TEL. TEL contexts may involve science applications, but the necessary background is provided for any science concepts not explicitly part of the TEL assessment targets.

The NAEP TEL framework and assessments, like NAEP science, include interactive computer-based tasks. In TEL, these are called scenario-based tasks and they engage students in rich multimedia tasks that require them to apply their knowledge and abilities to solve problems and achieve goals in realistic situations. Their intention, again as in science, is to provide for a deeper measure of students' understanding of engineering principles and their ability to fully engage in engineering practices than more traditional assessment item formats. The majority of the TEL assessment is based on these scenario-based tasks, with a smaller proportion of individual items using more traditional item formats.[12]

2.2.4 NAEP mathematics framework

The NAEP mathematics framework also has content and cognitive dimensions (see table 3). The 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. Mathematics differs from the NAEP science and TEL frameworks in that the cognitive dimension is organized by mathematical complexity levels, or a hierarchical description of the mathematical demands placed on the student. The mathematical complexity dimension was not part of the mathematics comparisons.

[12] This is in contrast to NAEP science, where most of the assessment is based on individual items.

Table 3. NAEP mathematics framework content areas and target percentages of assessment items, by grade

Mathematics content areas (and subtopics)	Framework target percentages[1]		
	Grade 4	Grade 8	Grade 12
Number properties and operations	40	20	10
Number sense	†	†	†
Estimation	†	†	†
Number operations	†	†	†
Ratios and proportional reasoning	†	†	†
Properties of number and operations	†	†	†
Mathematical reasoning using number	†	†	†
Measurement	20	15	[2]
Measuring physical attributes	†	†	†
Systems of measurement	†	†	†
Measurement in triangles	†	†	†
Geometry	15	20	30
Dimension and shape	†	†	†
Transformation of shapes and preservation of properties	†	†	†
Relationships between geometric figures	†	†	†
Position, direction, and coordinate geometry	†	†	†
Mathematical reasoning in geometry	†	†	†
Data analysis, statistics and probability	10	15	25
Data representation	†	†	†
Characteristics of data sets	†	†	†
Experiments and samples	†	†	†
Probability	†	†	†
Mathematical reasoning with data	†	†	†
Algebra	15	30	35
Patterns, relations, and functions	†	†	†
Algebraic representations	†	†	†
Variables, expressions, and operations	†	†	†
Equations and inequalities	†	†	†
Mathematical reasoning in algebra	†	†	†

† Not applicable. Framework target percentages are provided at the content area level, but not at the subtopic level.

[1] Framework target percentages reflect the percentage of assessment items to be devoted to each content area.

[2]At grade 12, Geometry and Measurement are combined into one content area. The target percentage for the combined content area (30 percent) is shown in the row for Geometry.

NOTE: This table displays the content dimension of the NAEP mathematics framework along with the target percentages of assessment time for the items specified for each content area at grades 4, 8, and 12. Each content area is broken down into subtopics, which are listed in the table. Each of the subtopics within the five content areas is further broken down into grade-specific objectives (not shown). The NAEP mathematics framework also includes a second dimension: levels of mathematical complexity (low, medium, and high) (not shown). Target percentages of assessment time across the three levels of mathematical complexity are 25 percent low, 50 percent moderate, and 25 percent high at all three grade levels.

SOURCE: National Assessment Governing Board (NAGB), *Mathematics Framework for the 2015 National Assessment of Educational Progress*, 2014.

2.2.5 Framework terminology

Exhibit 4 provides an overview of the NGSS and NAEP framework content dimension structure and the terminology used throughout the report. The units of analysis in the NAEP frameworks that most closely correspond to the NGSS performance expectations are the grade-specific objectives (content statements in science, assessment targets in TEL, and objectives in mathematics), which are the primary points of comparison for the data collection described in section 3. A review of the broader levels of the framework, described next, informed the study design.

Exhibit 4. 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.

2.3 Comparing the NGSS and NAEP STEM Framework Dimensions

In order to determine how to compare the NGSS with the NAEP frameworks, it is important to first consider how the dimensions of the frameworks relate to each other at the broadest level. Based on the main dimensions described in the previous sections (content and practices), there are clear areas where the NGSS and NAEP science, TEL, and mathematics frameworks relate to each other and can be compared. The identification of these areas informed the study design (see section 3) and confirmed the reasonableness of undertaking the comparisons. The text in this section is supported by the more detailed comparisons of the NGSS and NAEP framework dimensions provided in appendix B.

The NGSS and the NAEP science framework both have three broad, similarly defined content domains in physical, life, and Earth and space sciences, and both have sub-domains that cover a range of related topic areas (see exhibit B-1). There is also a clear relationship between the scientific and engineering practices in the NGSS and the NAEP science practices (see exhibit B-2 for an elaboration of

each NAEP science practice specified in the framework). In particular, the NGSS's practices of *planning and carrying out investigations*, *analyzing and interpreting data*, *engaging in argument from evidence*, and *asking questions and defining problems* relate to NAEP's *using scientific inquiry* practice. The practice of *constructing explanations and designing solutions* in the NGSS relates to both *using science principles* and *using technological design* in NAEP. NAEP's *using technological design* practice involves practical or real-world problems and requires the application of science principles to make design decisions to solve these problems. Through this practice, NAEP science includes some aspects of engineering design in the NGSS. However, the focus in NAEP science is more limited; a more complete engineering design process is included in NAEP TEL.

For technology and engineering, the NGSS can be compared with some, but not all, NAEP TEL assessment areas (see exhibit B-3). The most direct comparison is engineering design, which is a disciplinary core idea in the NGSS and a subarea within design and systems in the TEL framework. Also, some of the subareas of NAEP's technology and society assessment area are related to the second disciplinary core idea in the NGSS (links among engineering, technology, science, and society). In contrast, the third NAEP assessment area (information and communication technology) does not directly correspond to any of the core or component ideas in the NGSS, but may relate to some of the NGSS practices. In terms of practices, there is some correspondence between the NGSS's eight scientific and engineering practices and NAEP TEL's three broad engineering and technology practices (see exhibit B-4). Two of the NGSS's scientific and engineering practices, for example, have components specifically focused on engineering—defining problems (from *asking questions and defining problem*s) and designing solutions (from *constructing explanations and designing solutions*)—that relate to NAEP's *developing solutions and achieving goals* practice, in particular. Additionally, NAEP's *communicating and collaborating* appears to relate to the NGSS's *obtaining, evaluating, and communicating information*).

For mathematics, the areas for comparison between the NGSS performance expectations—which are in science and engineering—and the NAEP mathematics framework are not determined based on a direct comparison of the content dimensions. This is because while the NGSS emphasize the importance of mathematics and quantitative reasoning in science and engineering, the disciplinary core ideas in the natural sciences and engineering design disciplines do not explicitly describe the mathematics content and skills required. Areas for comparison are discerned, therefore, by comparing the scientific and engineering practices in the NGSS with the content areas and subtopics in NAEP (see exhibit B-5).

Four NGSS practices clearly involve the application of mathematics concepts and skills: *using mathematics and computational thinking*; *analyzing and interpreting data*; *planning and carrying out investigations*; and *developing and using models*. The other practices also include components related to the use of mathematics and quantitative reasoning, as described in the NGSS (see NGSS Lead States 2013, appendix F). Additionally, the NGSS crosscutting concept of *scale, proportion, and quantity* establishes expectations for using mathematical reasoning to make sense of systems. Two of the NAEP mathematics content areas—measurement and data analysis, statistics, and probability—are clearly related to these NGSS practices and this crosscutting concept. In addition, the NAEP content areas of

number properties and operations, geometry, and algebra include entire subtopics devoted to mathematical reasoning for various purposes.

To determine the extent to which these related areas actually overlap or align, the NGSS and NAEP frameworks in science, TEL, and mathematics must be compared at the most detailed (objective) level. How these comparisons were conducted is described in section 3, which covers study design and methods, and the results based on the data collected at this detailed level are described in section 4.

3. Study Design and Methods

This section describes (1) the overall study design—or, what is compared for each framework and why—and (2) the methods for data collection and analysis—or, how the comparisons were conducted. The methods for the science and TEL comparisons are presented separately from those for the mathematics comparisons because of the more restricted scope of the mathematics comparisons and differences in the methodological details.

3.1 Study Design

This study compares the relevant aspects of the NGSS with the appropriate NAEP STEM framework at the corresponding grades, as determined by the framework dimension review described in the previous section. The design focuses on comparisons at the most detailed level of the frameworks, which are the performance expectations in the NGSS and the grade-specific content objectives in the NAEP frameworks for the corresponding content areas. As described previously, the NGSS integrate both content and practices, and the study design considers both aspects of the performance expectations. Each component of the study design—science, TEL, and mathematics—is described in turn below.

3.1.1 Science comparisons

The most complete and parallel comparison was possible between the NGSS and the NAEP science framework. This is because each respective framework is intended to guide the development of science assessments. Understanding the similarities and differences between the two science frameworks can inform users about the degree of alignment between them and the potential for the alignment of assessments based on them.

For the science comparisons (research question 1), the study compared the NGSS performance expectations in the three content domains in the natural sciences (physical sciences, life sciences, and Earth and space sciences) with the NAEP content statements from the analogous content areas in the science framework. Performance expectations at grade 4, middle school, and high school were compared to NAEP content statements for grades 4, 8, and 12, respectively. The study design treats the content aspect of the NGSS performance expectations separately from the practices aspect, comparing the former to the NAEP content statements and the latter to the NAEP science practices. This design reflects two decisions by the research team, one regarding the grades selected for comparison and one regarding the integrated dimensions of the performance expectations.

With regard to the grades selected for comparison, the research team decided to restrict direct comparisons in science to the grade 4 NGSS performance expectations rather than include all performance expectations in the upper elementary grade-band (3-5). This decision was based on the assumption that grade 5 performance expectations would not be expected to be included in NAEP at grade 4. However, this may contribute to some underrepresentation of the alignment of the NGSS to NAEP in science at the upper elementary level since some grade 3 performance expectations also may be appropriate for comparison with NAEP grade 4.[13] To mitigate this concern about underrepresentation, the study design included an evaluation of cross-grade alignment, which is described in section 3.2.

With regard to the integrated dimensions of the NGSS performance expectations, the research team decided to conduct separate, but parallel, evaluations of the content and practices aspects in the NGSS performance expectations, so that each could be compared to their respective dimensions in the NAEP frameworks. (An example of the two aspects of an NGSS performance expectation is shown in exhibit 5.) Judging the content and practices aspects separately was deemed acceptable because, theoretically, any corresponding NAEP content statement could be crossed with a NAEP practice to produce performance expectations (and ultimately assessment items) that may be similar to those based on the NGSS.

Exhibit 5. Example of the content and practices aspects of an NGSS performance expectation

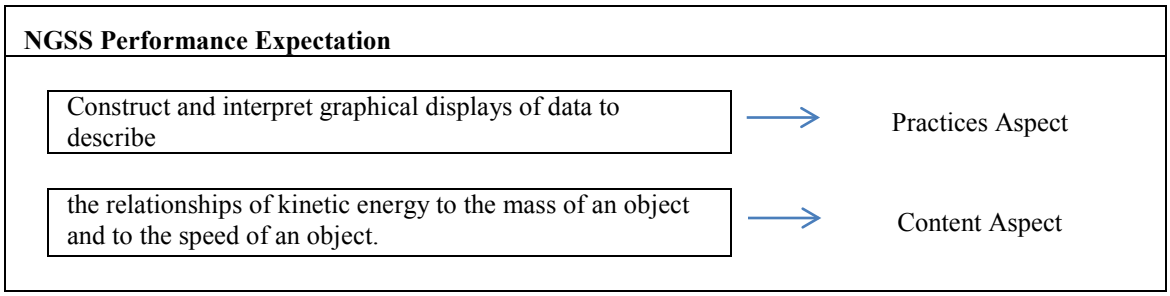


Table 4 shows the number of NGSS performance expectations and NAEP content statements in science by grade level and content area, which indicates the scope of the study. The science comparisons involved 14 NGSS performance expectations and 33 NAEP content statements at grade 4,[14] some 55 performance expectations and 43 content statements at middle school/grade 8, and 67 performance expectations and 49 content statements at high school/grade 12. At grade 4, the NGSS and NAEP objectives are similarly distributed across content areas, with more emphasis on physical sciences than on life sciences or Earth and space sciences. At grade 8/middle school, the NGSS have proportionately

[13] At the middle and high school levels, the NGSS provide performance expectations only for the grade-band endpoint. Thus, the corresponding grades in NAEP reflect the highest grade in the respective NGSS grade bands.

[14] There are far fewer NGSS performance expectations than NAEP content statements at grade 4 because the NGSS are intended to cover upper elementary content across the entire 3-5 grade band. When the full grade-band is considered, as shown in table 4, the total number of performance expectations (42) in the upper elementary grades exceeds the number of content statements in NAEP at grade 4. When only the most analogous grades (3 and 4) are considered, the number of NGSS performance expectations (29) is comparable to the number of NAEP content statements.

more objectives in life sciences, while NAEP has proportionately more in physical sciences. At grade 12/high school, the NGSS have an equal proportion in physical sciences and life sciences while NAEP has a greater proportion in physical sciences.

Table 4. Number and percentage of NGSS performance expectations in the science disciplines and NAEP science content statements, by grade and content area

Grade and content area	NGSS performance expectations		NAEP science content statements	
	Number	Percentage	Number	Percentage
Grades K-2	30	100	†	†
Physical sciences	12	40	†	†
Life sciences	7	23	†	†
Earth and space sciences	11	37	†	†
Grade 3	15	100	†	†
Physical sciences	4	27	†	†
Life sciences	8	53	†	†
Earth and space sciences	3	20	†	†
Grade 4	14	100	33	100
Physical sciences	7	50	15	46
Life sciences	2	14	7	21
Earth and space sciences	5	36	11	33
Grade 5	13	100	†	†
Physical sciences	6	46	†	†
Life sciences	2	15	†	†
Earth and space sciences	5	38	†	†
Middle school/grade 8	55	100	43	100
Physical sciences	19	35	16	37
Life sciences	21	38	12	28
Earth and space sciences	15	27	15	35
High school/grade 12	67	100	49	100
Physical sciences	24	36	23	47
Life sciences	24	36	13	27
Earth and space sciences	19	28	13	27
All grades	194	100	125	100
Physical sciences	72	37	54	43
Life sciences	64	33	32	26
Earth and space sciences	58	30	39	31

† Not applicable.

NOTE: The NGSS provide performance expectations in the science disciplines for each grade in elementary school (grades K-5) and for the grade band endpoints in middle school and high school. These are compared to the NAEP science content statements at grades 4, 8, and 12. Detail may not sum to totals because of rounding.

3.1.2 TEL comparisons

The comparison of the NGSS with the NAEP TEL framework is less exact because of the frameworks' divergent goals—the goal of the NGSS is to inform the development of a science

assessment that includes engineering content and practices, whereas the goal of NAEP TEL is to guide the development of a technology and engineering literacy assessment that does not require science knowledge per se. Thus, the results of this study cannot be used to directly compare assessments based on the NGSS and the NAEP TEL framework. However, the results can provide a better understanding of how well the technology and engineering portions of the NGSS align with NAEP TEL, as well as identify unique aspects of the TEL assessment.

For the TEL comparisons (research question 2), the study compared the NGSS performance expectations in the fourth content domain—engineering, technology, and applications of science (ETS)— with assessment targets in the NAEP TEL framework at grades 4, 8, and 12. Two types of ETS expectations were included in the TEL comparisons: those in engineering design in the 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. As with the science comparisons, the content and practices aspects of the NGSS performance expectations were treated separately, with the former compared to NAEP assessment targets and the latter to the NAEP technology and engineering practices.

Table 5 shows the number of NGSS performance expectations in ETS in engineering design and the sciences and the number of NAEP assessment targets in in each TEL assessment area by grade level, which indicates the scope of this part of the study. The TEL comparisons involved 7, 15, and 20 NGSS performance expectations for the 3-5,[15] middle school, and high school grade bands, respectively, and 47 NAEP assessment targets for each of grades 4, 8, and 12. There are far fewer NGSS performance expectations in ETS than NAEP TEL assessment targets because ETS is meant to constitute just part of an NGSS assessment in science, whereas NAEP TEL is a separate assessment. In the NGSS, the majority of ETS performance expectations are those in the sciences with connections to ETS, with only 3 or 4 engineering design performance expectations at each grade level. In NAEP, the greatest number of assessment targets is in design and systems, followed by technology and society, and then ICT at all three grades.

[15] Only 7 of the 9 performance expectations in the 3-5 grade band were compared with NAEP TEL at grade 4. Two of the science performance expectations were at grade 3, which were not included in the comparisons.

Table 5. Number and percentage of NGSS performance expectations in engineering, technology, and applications of science (ETS) and NAEP technology and engineering literacy (TEL) assessment targets, by grade level and content area

NGSS performance expectations			NAEP TEL assessment targets		
Grade level and content area	Number	Percentage	Grade level and content area	Number	Percentage
Grades K-2	12	100			
Engineering design	3	25			
Science - with connections to ETS[1]	9	75			
Grades 3-5	9	100	Grade 4	47	100
Engineering design	3	33	Design and systems	19	40
Science - with connections to ETS[2]	6	67	Technology and society	15	32
			Information and communication technology	13	28
Middle school	15	100	Grade 8	47	100
Engineering design	4	27	Design and systems	19	40
Science - with connections to ETS	11	73	Technology and society	15	32
			Information and communication technology	13	28
High school	20	100	Grade 12	47	100
Engineering design	4	20	Design and systems	19	40
Science - with connections to ETS	16	80	Technology and society	15	32
			Information and communication technology	13	28
All grades	56	100	All grades	141	100
Engineering design	14	25	Design and systems	57	40
Science - with connections to ETS	42	75	Technology and society	45	32
			Information and communication technology	39	28

† Not applicable.

[1] The K-2 grade band includes nine grade-specific science performances expectations with connections to ETS: four at kindergarten, two at grade 1, and three at grade 2.

[2] The 3-5 grade band includes six grade-specific science performances expectations with connections to ETS: two at grade 3, four at grade 4, and none at grade 5.

NOTE: The data in this table reflect the set of NGSS performance expectations (PEs) for engineering design in the K-2, 3-5, middle school, and high school grade bands as well as the subset of science PEs at grade 4, middle school, and high school with explicit connections to the disciplinary core ideas in ETS (engineering design and/or links among engineering, technology, science, and society). These are compared to the NAEP TEL assessment targets at grades 4, 8, and 12. Detail may not sum to totals because of rounding.

SOURCE: National Assessment Governing Board, *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress,* 2013. Next Generation Science Standards Lead States, *Next Generation Science Standards: For States, By State*s, 2013.

3.1.3 Mathematics comparisons

The mathematics comparisons are the most distinct and the most limited of the comparisons undertaken for the study. One reason is because the NGSS and NAEP mathematics framework have different purposes, with the former meant to inform assessments of science and the latter to guide the development of mathematics assessments. Since the resulting assessments are intended to be different, the results of the mathematics comparisons do not provide information on the degree of alignment of the respective assessments. A second reason has to do with the fact that the mathematics in the NGSS performance expectations is not explicit; rather it must be inferred from the descriptions of the performance expectations and the scientific and engineering practices. Thus, what is being compared is the mathematics that students may be required to use in responding to items and tasks developed based on the NGSS performance expectations with the mathematics that is expected in the NAEP framework across grades.

The mathematics component of the study can provide evidence as to whether the level of mathematics that students would be expected to use in NGSS-based assessments would be consistent with the NAEP mathematics framework and at which grade level(s). In other words, would the mathematics in an NGSS-based science assessment be aligned with the mathematics in NAEP at similar grades? This component of the study rounds out the evaluation of the degree to which the NGSS are aligned with the NAEP STEM frameworks based on an approach described in section 3.3.

For the mathematics comparisons (research question 3), all NGSS performance expectations that involve mathematics-related practices were compared to NAEP mathematics objectives across grades 4, 8, and 12.[16] This included NGSS performance expectations in both the natural sciences and in engineering design. Like the science comparisons, mathematics comparisons involving performance expectations in the natural sciences were restricted to grade 4, middle school, and high school. Like the TEL comparisons, mathematics comparisons involving performance expectations in engineering design were for the three grade bands (3-5, middle school, and high school). Unlike the science and TEL comparisons, the mathematics comparisons considered NAEP objectives at the corresponding grade as well as the next higher or lower grade level (i.e., grades 4 and 8 or grades 8 and 12).

3.1.4 Summary of the study design for science, TEL, and mathematics comparisons

Exhibit 6 illustrates the design for all three components of the study. It shows that the content and practices aspects of the NGSS performance expectations in the natural sciences and in ETS are compared separately to the content and practices dimensions of the NAEP science and TEL frameworks, respectively. It also shows that the content comparisons for science and TEL are bi-directional. For example, all of the NGSS performance expectations in the natural sciences are compared with all of the NAEP content statements in science, which allows reporting both in terms of the alignment of the NGSS to NAEP and the alignment of NAEP to the NGSS. The comparisons in mathematics, on the other hand, are unidirectional. All the NGSS performance expectations with mathematics-related practices are

[16] Nearly all of the NGSS performance expectations were represented among those involving mathematics-related practices.

compared to NAEP objectives, but it is not possible (or appropriate) to compare the NAEP mathematics objectives to the NGSS since they are science and engineering standards. Reporting is limited, by nature, to the coverage of the NGSS's mathematics-related practices in the NAEP mathematics framework.

Exhibit 6. Study design for the comparisons of the NGSS with the NAEP science, TEL, and mathematics frameworks

NGSS	NAEP
Performance expectations in the natural sciences Content aspect ⟷ Practices aspect → … at grade 4 … at middle school … at high school	 Content statements in science Science practices … at grade 4 … at grade 8 … at grade 12
Performance expectations in engineering, technology, and applications of science (ETS) Content aspect ⟷ Practices aspect → … at grade 4 (or 3-5 grade band) … at middle school … at high school	 Assessment targets in TEL TEL practices … at grade 4 … at grade 8 … at grade 12
Performance expectations involving mathematics-related practices → … at grade 4 (or 3-5 grade band) … at middle school … at high school	Mathematics objectives [1] … at grade 4 (and grade 8) … at grade 8 (and grade 12) … at grade 12 (and grade 8)

[1] For mathematics comparisons, NGSS performance expectations were compared with NAEP objectives at the corresponding grade level and the next higher or lower grade level in the framework.

NOTE: The natural sciences includes the NGSS performance expectations in physical, life, and Earth and space sciences at grade 4, middle school, and high school. Performance expectations in engineering design are by grade bands (3-5, middle school, and high school). Double-headed arrows indicate comparisons that were made in both directions (NGSS performance expectations compared to NAEP objectives and NAEP objectives compared to NGSS performance expectations). Single-headed arrows indicate comparisons that were made in only one direction (NGSS performance expectations compared to NAEP science and TEL practices and to NAEP mathematics objectives).

3.2 Methods Used for the Science and TEL Comparisons

The general approach to the science and TEL comparisons was adapted from methods developed and used for prior framework comparison studies commissioned by NCES, including a recent comparison of the mathematics and science frameworks in NAEP and the Trends in International Mathematics and Science Study (TIMSS).[17] The comparisons of the NGSS with the NAEP science and TEL frameworks included three main stages:

1. **Content mapping**, during which the research team, guided by the design considerations described earlier, prepared content-mapping documents that grouped the relevant portions of

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

the NGSS performance expectations with NAEP framework objectives that covered related content at the corresponding grade level for review and rating.

2. **Review and rating (data collection)**, which included convening and facilitating an external expert panel that reviewed the content mapping documents and provided ratings of the degree of alignment between the NGSS performance expectations and the content and practices in the NAEP science and TEL frameworks.

3. **Data analyses**, which included cleaning and aggregating the data collected from the expert panel and conducting the analyses presented in this report.

3.2.1 Content mapping

The first step in the science and TEL comparisons was for the research team (which has expertise in the NAEP frameworks and assessments) to prepare preliminary content-mapping documents. The purpose of the content-mapping documents was to facilitate data collection by identifying the content from the standards and frameworks that was potentially aligned and could be directly compared.

The research team prepared two sets of content-mapping documents: one set for the science comparisons and one set for the TEL comparisons.

- Science comparisons: The set included a content-mapping document for each content area in each grade, or nine in total (one each for the physical sciences, life sciences, and Earth and space sciences at each of grade 4, grade 8/middle school, and grade 12/high school); and

- TEL comparisons: The set included a content-mapping document for each grade, or three in total (one each for grade 4/3-5, grade 8/middle school, and grade 12/high school). These were organized within grade by the two different types of NGSS performance expectations in engineering, technology, and applications of science (ETS): performance expectations in engineering design and those in the sciences with connections to ETS.

The content-mapping documents grouped the relevant NGSS performance expectations in the sciences and in ETS with NAEP framework objectives in science and/or TEL that covered related content at the corresponding grade level, resulting in "groupings" to be rated for content similarity by the expert panel.[18] For example, the content-mapping document for grade 8 physical sciences identified preliminary groupings of middle school NGSS performance expectations and grade 8 NAEP content statements from related topics in physical sciences. The content-mapping document for grade 4 in TEL

[18] For ease of discussion, this report uses the generic term "objective" as an equivalent to a performance expectation, a content statement in science, or an assessment target in TEL. This manifests in two ways. In this section, the terminology is generally used in place of the more particular "content statements" or "assessment targets" so that the methods for the science and TEL comparisons can be described in an integrated and streamlined way. In this section and in the discussion of the results (in section 4), the terminology is used when referring generally to "grouped objectives" (e.g., performance expectations and content statements grouped for comparison) and "non-grouped objectives" (e.g., performance expectations and content statements or assessment targets with no corresponding content in the counterpart framework at the corresponding grade level).

identified NGSS performance expectations in the 3-5 grade band in engineering design and grade 4 performance expectations in physical sciences, life sciences, and Earth and space sciences with connections to ETS that were grouped for comparison with grade 4 NAEP TEL assessment targets covering related content.

In general, science groupings were within the same content area, but there were some NGSS performance expectations that were grouped with NAEP content statements from a different content area (e.g., a performance expectation in physical sciences mapped to a content statement in Earth and space sciences with overlapping content). For the TEL groupings, NAEP assessment targets from all three TEL assessment areas (design and systems, technology and society, and information and communication technology) were included, as appropriate.

The NGSS served as the basis for the content groupings in order to directly evaluate the extent to which the NGSS performance expectations were covered by the NAEP frameworks. Therefore, each performance expectation mapped to only one content grouping. In some cases, a single NGSS performance expectation was grouped with multiple NAEP objectives. In other cases, a single NAEP objective was grouped with multiple NGSS performance expectations. Some NGSS performance expectations were not grouped with any NAEP objectives, and some NAEP objectives were not grouped with any NGSS performance expectations if there was no corresponding content in the counterpart framework at the corresponding grade level. These are referred to in the report as "non-grouped" objectives. Examples of the different types of grouped and non-grouped objectives are shown in exhibit C-1 in appendix C.

There also were instances—in the science comparisons only—where a NAEP content statement that covered multiple science concepts was split into two parts and each part was then grouped with one or more separate NGSS performance expectations. An example of a split NAEP content statement is included in exhibit C-2.

3.2.2 Review and rating (data collection)

Convening and training the expert panel

For the data collection phase, the research team convened a panel of experts for a 3-day meeting in July 2014, to undertake the review and rating of the alignment of the NGSS with the NAEP science and TEL frameworks. The first 2 days of the expert panel meeting were devoted to the science comparisons, and the third day was focused on the TEL comparisons. On the third day, the expert panel also provided input on the study design and procedures for the mathematics comparisons, which were conducted at a later time (as described in section 3.3).

The expert panel for the science and TEL comparisons consisted of subject area curriculum and assessment experts experienced in working with the NGSS and/or NAEP (see appendix A). The panel had seven members, all of whom were present for the comparison of life sciences, and six of whom were

present for the physical sciences, Earth and space sciences, and the TEL comparisons.[19] All members had some experience with NGSS-related activities, including three who served on the writing team, one involved in the NRC report on assessing the NGSS (NRC 2014), one who authored a paper comparing NGSS with other large-scale assessments (Alonzo 2013), and one who authored a report on translating the NGSS to instruction (Bybee 2013). Five members also had direct experience with NAEP, including five who served on the Science Standing Committee or Science Framework Development Committee, and one who was a consultant on the NAEP assessment development. Additionally, two members had served on prior NAEP comparison studies, and two were STEM assessment directors or coordinators in their state or district. Specific TEL expertise included one member who served on the NAEP TEL framework committee and another with experience as an e-learning and assessment expert.

The expert panelists participated in two trainings related to the science comparisons. The first training was a webinar, and the second training was integrated with the expert panel meeting. The webinar training was held 1 week before the expert panel meeting, during which the research team explained the goals and methods of the study. The purpose of the webinar was to familiarize panelists with meeting procedures and ensure that the meeting time could be devoted mainly to obtaining data from the panelists.

The second training occurred at the beginning of the first day of the expert panel meeting. It included a formal overview of the NGSS and the NAEP science framework, instruction in the procedures for comparing content and practices, and a practice rating exercise. In the exercise, the panelists rated a training set of science objectives that were similar to those in the NAEP framework using the rating scale for content similarity and criteria for practices alignment that were developed for the study (described in the next subsection). The purpose of the exercise was to ensure consistency in the interpretation and application of the rating scales and criteria.

Training specifically for the TEL comparisons occurred on the third day, immediately prior to the start of that component of the meeting. It included a formal overview of the NAEP TEL framework and instruction on the procedures specific to the TEL comparisons. Although there was no separate practice rating exercise for TEL, the expert panelists worked through the first few comparisons as a group.

Rating the alignment of the NGSS and NAEP science and TEL frameworks

For both the science and TEL comparisons, the expert panel reviewed and rated the alignment of the NGSS and NAEP frameworks at the:

- Objective level. In this process, the panel reviewed grouped and non-grouped objectives and provided two main types of ratings in parallel: content similarity and practices alignment.

[19] One expert panel member had to leave the meeting at the end of the first day.

(Example data collection forms used for the science and TEL objective-level ratings are presented in exhibit C-3 and exhibit C-4, respectively.)

For the science comparisons, the expert panel rated the alignment of the NGSS and NAEP frameworks at two additional levels:

- Content area level. In this process, the panel provided a rating of content similarity for each content area as a whole (physical sciences, life sciences, and Earth and space sciences) at each grade.
- Overall framework level. In this process, the panel provided two similarity ratings of the NGSS and the NAEP science framework overall at each grade level—one rating considering *content* alone and a second rating considering both *content and practices* together.

Ratings at the content area level and the overall framework level were not undertaken for TEL because of the starker differences between the NGSS and NAEP TEL compared to science—with the NGSS including ETS as just one of four disciplines in the domain of science and NAEP treating TEL as a domain wholly separate from science with content areas that do not correspond to those in the NGSS. For TEL, the objective-level ratings are sufficient to understand the similarity of content between the NGSS and NAEP. A more extensive picture is possible and necessary for the comparison of the NGSS with the NAEP science framework, both of which are intended to guide the development of science assessments that can be directly compared.

Ratings at the objective level

For the objective-level ratings, the panelists first reviewed the preliminary groupings of NGSS and NAEP objectives (i.e., the content-mapping documents). This process was the same for both the science and the TEL comparisons. The panelists discussed the preliminary groupings and revised some by consensus by adding or removing some of the NAEP objectives from a group to improve the degree of overlap or by "ungrouping" an NGSS performance expectation that the panel felt was not comparable to the content in the corresponding NAEP framework and could not be directly compared.

Content similarity ratings

The first objective-level rating for the science and TEL comparisons was of "content similarity." Panelists rated each grouping on a scale from 1 to 4, where:

4 = Exactly or almost the same

3 = Quite similar, but with some differences

2 = Quite dissimilar, but with some overlap

1 = Substantially or wholly different

A separate rating of 0 was assigned to non-grouped objectives to indicate their inclusion in only one standards/framework document.

The expert panelists were guided by the following questions in assigning their ratings:

- For science: "How similar is the science content that could be measured by items/tasks developed to assess the NGSS performance expectations in the sciences compared to the NAEP content statements?"
- For TEL: "How similar is the science and engineering content that could be measured by items/tasks developed to assess the NGSS performance expectations in ETS compared to the NAEP TEL assessment targets?"

Panelists were asked to consider various aspects in answering these questions and providing a rating. For example: "What types of items or tasks could be developed to assess the content covered in the NGSS performance expectation compared to grouped NAEP objective(s)? What is the primary emphasis, depth, and breadth of the content covered in each? How advanced is the content covered in each? Are specific portions of the content in one document explicitly included or excluded in the other document?"[20]

The process for assigning the ratings included individual work and group discussion. In the first stage, panelists worked individually to assign a preliminary independent rating (1-4) to each grouping; non-grouped objectives were automatically assigned a rating of 0. In the second stage, which occurred after individual initial ratings were completed for each grade and content area, the panelists discussed their ratings as a group and then individually assigned a final content rating to each group of objectives (making adjustments following group discussion as appropriate). Only the final ratings were used in the analyses. In addition, panelists were encouraged to provide written comments supporting their ratings.

[20] Experts were instructed not to rely only on the specific wording of the performance expectation, but to consider the clarifications and assessment boundaries and the descriptions of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts described in the NGSS. In evaluating NAEP objectives, the experts consulted the descriptions in the science and TEL frameworks as well as the content boundaries and content statement elaborations in the separate NAEP science assessment and item specifications document (NAGB 2007b).

Grade-level alignment (science only) [21]

For the science comparisons, panelists also considered whether or not the NGSS performance expectations or NAEP content statements might be similar to one or more objectives at a different grade level in the counterpart framework; this is referred to as grade-level alignment (or alignment to a lower or higher grade). For example, the 3-5 grade band includes some NGSS performance expectations in the sciences in grades 3 and 5 that were identified by expert panelists as covering content included in NAEP grade 4 objectives in science.

Grade-level alignment was done for non-grouped objectives as well as grouped objectives at the corresponding grade that were rated as a 1 ("substantially or wholly different") or a 2 ("quite dissimilar, but with some overlap"). Panelists suggested specific objective(s) from the counterpart framework at a higher or lower grade level when appropriate, and these were discussed with the group. In most cases, consensus was reached during group discussion. When it was not, the research team leader reviewed the alternative objectives proposed by panelists after the meeting and made the final decision about which objectives from other grade levels to use in the data analysis.

Practices alignment

Another type of objective-level rating, which occurred in parallel with the content similarity rating, was the alignment of the NGSS performance expectations with the NAEP science and TEL practices. Ratings of practices alignment were conducted for all grouped and non-grouped performance expectations. This activity proceeded by grade level within each content area for science and by grade level for TEL concurrently with the content similarity ratings. Experts considered the practices aspect of each performance expectation and compared this to the description of the practices in the NAEP framework. They were instructed not to rely only on the specific wording of the performance expectation but to also consult descriptions of the associated scientific and engineering practices in the NGSS.

Raters used a two-category scale (1 = primary; 2 = secondary) to answer the following question for each NGSS performance expectation:

- <u>For science</u>: "To which NAEP science practice(s) are the scientific and engineering practices required by the NGSS performance expectations in the sciences aligned?"

[21] Grade-level differences are less relevant for the TEL comparisons than for the science comparisons. This is because alignment at other grade levels is most significant as it relates to the progression of science content across grades, and knowledge of specific science content is not included in the TEL assessment. Since the NGSS are intended to guide assessments in science, not assessments in TEL, the degree of similarity between the NGSS performance expectations in ETS and the knowledge and skills specified in the TEL assessment objectives at the corresponding grade or grade band level is the most appropriate level of analysis. In addition, for engineering design (which most directly corresponds to one of the assessment areas in TEL), performance expectations are provided at the grade band level (3-5, middle school, and high school), not for individual grades.

- For TEL: "To which NAEP TEL practice(s) are the scientific and engineering practices required by the NGSS performance expectations in ETS aligned?"

Individually, panelists assigned a primary NAEP practice (a rating of 1) based on a hierarchy that prioritized the practices (see exhibit 7). According to this hierarchy, when an NGSS performance expectation was judged to be aligned to more than one NAEP practice, the primary practice was determined by the one with the higher priority. For example, in science an objective aligned with both the highest priority practice (*using technological design*) and another practice (such as *using science principles*) would be assigned a primary practice of *using technological design*. Likewise, an NGSS performance expectation would only be considered as having a primary alignment with the lowest priority practice (e.g., in science, *identifying science principles*) if it was not aligned with any of the other three practices. In TEL, the practice of *communicating and collaborating* had the highest priority and *understanding technological principles* had the lowest priority. When objectives aligned to more than one practice, raters used a secondary rating (a rating of 2) to identify those aligned that were lower in the hierarchy than the primary practice. Panelists assigned neither a primary nor secondary practice if they determined that the performance expectation was not aligned with any NAEP practice.

The use of a hierarchy was necessary because the NAEP practices were designed to include some overlap and themselves are somewhat hierarchical (particularly for science) in terms of the cognitive demands and specific skills that each requires. The hierarchy for the assignment of primary practice in science and TEL ensured that certain practices would not be underrepresented in the results, as they might be in ratings made more subjectively.

Exhibit 7. Hierarchy for rating practices alignment

Hierarchy of NAEP Science Practices[1]	
If the NGSS PE is …	Then:
Aligned with both USI and either ISP or USP	Assign USI as primary and ISP or USP as secondary
Aligned with both UTD and either ISP or USP or with USI	Assign UTD as primary and ISP, USP, or USI as secondary
Aligned with both USP and ISP	Assign USP as primary and ISP as secondary
Aligned only with ISP	Assign ISP as primary
Hierarchy of NAEP TEL Practices[2]	
If the NGSS PE is …	Then:
Aligned with both CC and either DSAG or UTP	Assign CC as primary
Aligned with both DSAG and UTP	Assign DSAG as primary
Aligned only with UTP	Assign UTP as primary

[1] The NAEP science practices include: *identifying science principles* (ISP), *using science principles* (USP), *using scientific inquiry* (USI), and *using technological design* (UTD).

[2] NAEP TEL practices include: *understanding technological principles* (UTP), *developing solutions and achieving goals* (DSAG), and *communicating and collaborating* (CC).

SOURCE: National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* 2012. National Assessment Governing Board, *Science Framework for the 2015 National Assessment of Educational Progress*, 2014. National Assessment Governing Board, *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress,* 2013.

During the group discussion of the objective-level content similarity ratings, the panel also discussed the practices alignment for the performance expectations and then individually provided their final ratings. Only the final ratings were used in the analysis.

Ratings at the content area level (science only)

After completing the objective-level ratings in each science content area, panelists used the 4-point rating scale to assign a holistic rating of content similarity at the content area level. They individually assigned preliminary ratings of the content similarity between the NGSS and NAEP for each of the three science content areas at each grade level. After assigning each preliminary rating, the panelists discussed their ratings as a group and then individually assigned a final rating to each content area. Only final ratings were used in the analyses.

Overall framework ratings (science only)

At the completion of the science comparisons, panelists rated the similarity between the NGSS and NAEP science at the overall framework level. They used the 4-point scale to provide two similarity ratings at each grade level:

- "content only," which considered only the similarity of science content covered in the NGSS and the NAEP science framework; and
- "content and practices," which considered the coverage of both content and practices.

Due to time constraints, these overall framework ratings included only one round of ratings (i.e., no group discussion and final rating), unlike the process at the objective and content area levels.

3.2.3 Data analyses

Data analyses primarily involved aggregating expert panelists' individual ratings at the objective level using decision rules to arrive at single ratings of:

- Content overlap;
- Content alignment;
- Grade-level alignment (science only); and
- Practices alignment.

In addition, science analyses were conducted based on ratings at the content area and overall framework levels. Other analyses combined the objective-level quantitative data with qualitative data provided by expert panel comments. (See exhibit C-5 for a list of the tables and exhibits and the data sources associated with each of the analyses described in this section.)

Content overlap

The first analysis calculates the extent of content overlap, which is the number or proportion of NGSS performance expectations and NAEP objectives that were grouped, or judged as covering related content at the corresponding grade level. Content overlap indicates the potential for content alignment between the NGSS and NAEP science and TEL frameworks at specific grade levels. The number or proportion of non-grouped objectives indicates content that is unique to NGSS or NAEP at the corresponding grade. Analyses were conducted separately for each grade level.

The number of grouped NGSS performance expectations always corresponds to the total number of groupings because each NGSS performance expectation mapped only to one grouping.[22] This is not the case for NAEP because objectives could appear in multiple groupings and a NAEP objective was counted as grouped if it appeared in at least one grouping. Additionally, some NAEP science content statements were split into two parts; if only one part was grouped, it contributed 0.5 to the number of grouped objectives and 0.5 to the number of non-grouped objectives.

Content alignment

Content alignment analyses were conducted for both the science and TEL comparisons based on the number and percentage of NGSS performance expectations and NAEP objectives that were rated as "similar" to their counterparts at the corresponding grade. Content alignment indicates that grouped objectives in the NGSS and NAEP science or TEL frameworks are similar enough in depth, breadth,

[22] As described in section 3.2.1, the NGSS were used as the basis for the groupings, so each performance expectation corresponded to one grouping.

detail, and focus of content that they could lead to similar assessment items at the corresponding grade level.

A grouping of NGSS performance expectations and NAEP objective(s) was defined as "similar" when two-thirds or more of the panelists assigned the grouping a rating of 3 ("quite similar, but with some differences") or 4 ("exactly or almost the same"). When this criterion was not met, the grouping was assigned a rating of "not similar." Thus, an aggregate rating of "similar" or "not similar" was assigned to every grouping based on the individual panelists' ratings. In addition to grouped objectives not meeting the two-thirds criterion, a rating of "not similar" was assigned to non-grouped NGSS performance expectations and NAEP objectives (those with no related content at the corresponding grade of the counterpart framework). For the purpose of analyses, a rating of "similar" was assigned a value of 1, and a rating of "not similar" was assigned a value of 0.

The degree of content alignment at the objective level was calculated in both directions (the NGSS to NAEP and NAEP to the NGSS) for both the science and TEL comparisons—one based on the number and percentage of performance expectations (as they aligned with NAEP) and the other based on the number and percentage of NAEP objectives (as they aligned with the NGSS). Each NGSS performance expectation mapped to only one grouping, so if the grouping was rated as "similar," the NGSS performance expectation received a "similar" rating. In contrast, NAEP objectives could appear in multiple groupings. In cases where an individual NAEP objective was mapped to multiple NGSS performance expectations, the NAEP objective received a "similar" rating if at least one of these groupings was rated as "similar."

For science, further adjustments were required to account for cases where a NAEP science content statement was split into two parts, with each part being mapped to one or more groupings. In these cases, the partial content statement ratings were weighted at half the value of a full content statement rating.[23] (See exhibit C-2 for an example of a split NAEP content statement from grade 8 physical science (P08.04) and the resulting partial and overall content statement ratings.[24])

Although the general method of calculating content alignment was the same for the science and TEL comparisons, the results are presented differently. Content alignment results for science show the NGSS to NAEP and NAEP to the NGSS side by side in a single display for each corresponding grade and science content area (physical sciences, life sciences, and Earth and space sciences). For TEL, there are separate results for the NGSS to NAEP and NAEP to the NGSS alignment at each grade level that are disaggregated based on the different content dimensions in the NGSS and the TEL framework.

[23] If a content statement appeared in more than one grouping, the ratings were weighted to sum to 1 for that objective. For example, if part of a content statement appeared in each of two groupings and was rated as "similar" in one grouping and "not similar" in the other grouping, then 0.5 content statements would count toward the total number of "similar" content statements and 0.5 content statements would count toward the total number of "not similar" content statements.

[24] None of the NAEP TEL assessment targets were divided into sub-targets. Therefore it was not necessary to apply any weights to the data during the analysis of the NAEP TEL content.

Grade-level alignment (science only)

Grade-level alignment analyses further expanded on the data obtained from objective-level content similarity ratings for science. These analyses made use of the data on alternative groupings at other grades. Grade-level alignment analyses determined the percentage of NGSS performance expectations and NAEP content statements that were aligned to content at a different grade level (lower or higher) in the other document.

For objectives with aggregate ratings of "not similar" at the corresponding grade level (which includes non-grouped objectives and grouped objectives rated as "not similar"), the research team identified whether or not the panelists indicated that the (associated) NGSS performance expectation or NAEP content statement(s) were aligned to objectives at a different grade level in the other document. Each of these NGSS performance expectations or NAEP content statements was assigned one of three labels:

- "aligned at a lower grade," which indicates that the objective was aligned to an objective in the counterpart framework at a lower grade that was proposed by panelists and agreed upon by consensus during group discussion. [25]
- "aligned at a higher grade," which indicates that the objective was aligned to an objective in the counterpart framework at a higher grade that was proposed by panelists and agreed upon by consensus during group discussion.
- "not aligned," which indicates that the objective was not aligned to a specific objective in the counterpart framework at any grade level (rated as not similar at the corresponding grade and no alternative objective was aligned at a lower or higher grade).

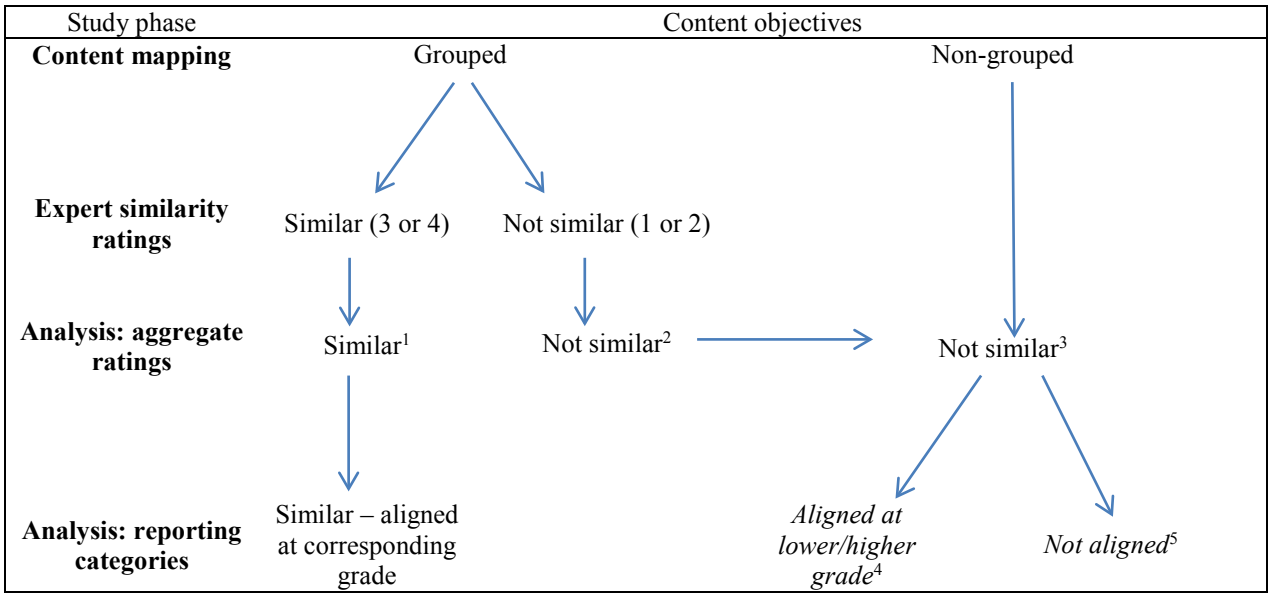
For example, a middle school NGSS performance expectation might not be rated as "similar" to any NAEP grade 8 content statement, but was rated as "aligned at a lower grade level" because panelists considered it similar to a content statement in the NAEP grade 4 science framework. Likewise, a NAEP grade 8 content statement might not be "similar" to any middle school performance expectation in the NGSS, but was rated as "aligned at a higher grade level" because panelists determined it was similar to a performance expectation at the high school level.

Since grade 4 is the lowest grade in the NAEP framework, "aligned at a lower grade" was not applicable for the alignment of the NGSS to NAEP at grade 4. Similarly, "aligned at a higher grade" was not applicable at grade 12/high school for either alignment direction (the NGSS to NAEP or NAEP to the NGSS).

[25] A consensus approach was used to determine whether an objective was aligned at a higher or lower grade level (in contrast to the two-thirds criterion used to determine whether or not an objective was "similar at the corresponding grade level"). The research team leader had the overriding vote if consensus was not reached during the meeting.

Exhibit 8 provides a visual representation of how expert similarity ratings were aggregated and how analytic and reporting categories were developed for content alignment and for grade-level alignment.

Exhibit 8. Visual representation of the content rating and aggregation process



[1] Similar indicates that at least two-thirds of the expert panelists rated the objectives as similar (3 or 4) on the four-point rating scale.

[2] Not similar indicates grouped objectives that more than one-third of the experts rated as not similar (1 or 2).

[3] Not similar indicates grouped objectives with an aggregate rating of not similar and objectives that all panelists agreed were non-grouped.

[4] Aligned at a lower/higher grade indicates objectives that were aligned in the counterpart framework at a lower or higher grade using the alternative groupings proposed and discussed by panelists.

[5] Not aligned indicates objectives that were not aligned to a specific objective in the counterpart framework at any grade level.

NOTE*:* Italics indicates that these analyses/aggregations were only conducted for the science comparisons. For TEL, grade-level alignment was not conducted, so all objectives were rated either "similar" or "not similar," as defined in notes 1 and 3.

Practices alignment

Two analyses related to practices alignment were conducted based on the objective-level practices alignment ratings for the science and TEL comparisons.

The first analysis calculated the distribution (number and percentage) of NGSS performance expectations across the NAEP science practices (or NAEP TEL practices) at each grade level. To aggregate across individual panelists' ratings, the research team determined the primary practice of each NGSS performance expectation as the NAEP science (or TEL) practice most frequently identified as primary by panelists (rating = 1), provided that at least three panelists agreed. In cases where no primary NAEP science (or TEL) practice could be determined based on the aggregation, the NGSS performance expectation was designated as having no primary alignment to any NAEP science (or TEL) practice. Data on alignment to secondary practices (rating = 2) were not used in the analysis.

The second analysis examined the extent of alignment between the NGSS scientific and engineering practices and the NAEP science (or TEL) practices. It calculated the distribution (number and percentage) of NGSS performance expectations across the eight NGSS practices.[26] For each NGSS practice, the analysis determined the number of associated performance expectations that were judged by panelists to have a primary alignment with each NAEP practice. As described above, the primary NAEP science practice was determined as the practice most frequently identified by panelists, provided that at least three panelists agreed.

Additional alignment analyses (science only)

For the science comparisons, three additional alignment analyses were conducted.

The first analysis was content alignment by crosscutting concept. It was based on the objective-level content similarity ratings and calculated the distribution (number and percentage) of NGSS performance expectations across the crosscutting concepts and determined the extent to which the performance expectations within each crosscutting concept were aligned with the NAEP science content statements at the corresponding grade level.[27] The analysis determined the number of NGSS performance expectations associated with each crosscutting concept from each content domain and the percentage of performance expectations in each crosscutting concept that had aggregate content similarity ratings of "similar" and "not similar."

The second analysis examined alignment at the content area level. It drew on data collected from experts on holistic content similarity ratings of each science content area. Again, the two-thirds criterion was applied to obtain aggregate ratings of "similar" and "not similar" for the content areas as a whole at each grade level.

The third analysis examined alignment at the overall framework level. It drew on data collected from experts on holistic ratings of the similarity between NGSS and the NAEP science framework at each grade level (for "content only" and for "content and practices"). Again, the two-thirds criterion was applied to obtain aggregate ratings of "similar" or "not similar."

[26] Each performance expectation is classified to a primary scientific and engineering practice in the NGSS.

[27] Each performance expectation is classified to a primary crosscutting concept in the NGSS.

Combined science and TEL analyses

Two final quantitative analyses looked across the results from the science and TEL comparisons to provide an overall view of the extent of the (1) content overlap and (2) content alignment between the NGSS and the NAEP science and TEL frameworks. These analyses were based on the entire set of NGSS performance expectations—including those in the three science disciplines compared to the science and TEL frameworks and those in engineering design compared to the TEL framework.[28] They also considered the cross-grade alignment data in science to cover the NGSS elementary grade band more comprehensively.

The combined content *overlap* analysis calculated the total number of NGSS performance expectations at each grade band that were grouped with NAEP science content statements and TEL assessment targets at the corresponding grade, disaggregated by those in the natural sciences and those in engineering design. NAEP grades 4, 8, and 12 correspond to the NGSS grade bands for grades 3-5, middle school, and high school, respectively. For science, the alternative grade-level groupings were used to also calculate the number of performance expectations (1) from the lower and higher grades within the 3-5 grade band (grade 3 or 5, respectively) that were grouped with NAEP at grade 4, and (2) from all grade bands (3-5, middle school, and high school) that were grouped with NAEP content statements at a higher or lower grade band. The cross-grade analysis within the 3-5 grade band is not applicable for middle school and high school, since the NAEP grades (8 and 12) are the same as the NGSS grade band endpoint.

The combined content *alignment* analysis calculated the total number of NGSS performance expectations at each grade band that were aligned (rated as similar) to NAEP science and/or TEL objectives at the corresponding grade, disaggregated by those in the natural sciences and those in engineering design. The results were calculated separately for science NGSS performance expectations aligned only with the NAEP science framework, science performance expectations aligned with both the NAEP science and TEL frameworks, and engineering design performance expectations aligned only with the TEL framework. These were used to determine the total number of NGSS performance expectations aligned with the NAEP science or TEL frameworks.

Summaries of the comparison of the NGSS performance expectations across the four content domains with the NAEP science and TEL assessment frameworks are provided for each grade band in appendix D.

Qualitative content analyses

The report includes additional, supporting presentations of qualitative data. Content comparison exhibits (appendix E for science and appendix F for TEL) provide detailed descriptions of the content of

[28] All performance expectations in the sciences were compared with content statements in the NAEP science framework. Performance expectations in engineering design and those in the sciences with connections to ETS were compared with assessment targets in the TEL framework. The engineering design performance expectations were not compared to the NAEP science framework since these performance expectations do not specify science content.

each of the NGSS performance expectations, NAEP science content statements, and TEL assessment targets by content area and grade. They are organized into sections by groupings of NGSS and NAEP objectives rated as "similar" or "not similar" and by non-grouped objectives that were judged as unique to each program. They draw on the expert panel content similarity ratings and comments to provide information about the areas of similarity and dissimilarity between the NGSS and NAEP, including some cross-grade differences (for science). Summaries of the detailed content comparison exhibits are provided in the results sections describing the science comparisons (section 4.1) and TEL comparisons (section 4.2).

3.3 Methods Used for the Mathematics Comparisons

The mathematics comparisons included the same three stages as the science and TEL comparisons (document mapping, review and ratings, and data analyses), although the details of the procedures were different 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).

3.3.1 Document mapping

The first step in the mathematics comparisons was for the research team to conduct an initial document-mapping procedure based on input received during the science and TEL expert panel meeting. The resulting mathematics comparison documents took a different form and required a different approach to preparation than those for the science and TEL comparisons.

Preliminary groupings of NGSS performance expectations and NAEP mathematics objectives were prepared using two sources of information: (1) the connections to the Common Core State Standards for Mathematics (CCSS-M) provided in the NGSS and (2) the results from a previous alignment study conducted by the NAEP Validity Studies (NVS) panel that mapped the CCSS-M standards to grade-specific objectives in the NAEP mathematics framework (Hughes et al. 2013).

The first source was used to identify the mathematics-related performance expectations at each grade and the standards in the CCSS-M to which they were connected (as noted in the NGSS). [29] The second source was used to identify the initial set of grouped NAEP mathematics objectives based on links between specific CCSS-M standards and NAEP objectives from the NVS alignment study. The resulting mathematics comparison documents were organized into sets of NGSS performance expectations by NGSS mathematics-related practices. Separate documents were prepared for each grade level (grade 4, middle school, and high school).

[29] This set included most of the NGSS performance expectations in the sciences and all of those in engineering design.

3.3.2 Review and ratings (data collection)

Convening the expert panel

For the data collection phase, a panel of experts was convened to rate the alignment between the NGSS performance expectations involving mathematics-related practices and the objectives in the NAEP mathematics framework. The mathematics panel had four members (see appendix A). Three members were experts on the NAEP mathematics framework and assessments, and one member was from the NGSS writing committee and experienced with the development of connections between the NGSS and CCSS-M. The fourth panelist also served on the science and TEL expert panel. In addition, three of four panelists also had expertise and experience in science education. The mathematics expert panel meeting occurred on two days in September 2014. The research team leader conducted follow-up reviews and discussions with the mathematics expert panelists over a period of 4 weeks to complete the mathematics comparisons.

Rating the alignment of the NGSS and NAEP mathematics framework

The rating process for the mathematics comparisons was substantially different from the processes for the science and TEL comparisons. One difference is that the mathematics ratings were based on dichotomous judgments (yes/no) of the alignment of NAEP objectives with the inferred mathematics involved in the NGSS performance expectations rather than the 1-4 content similarity scale used for judging alignment for science and TEL.

Another difference is that the initial mapping document underwent a much more extensive review and revision. Extensive revisions were necessary because while the NGSS identified potential connections to the CCSS-M for the performance expectations, in many cases the panel judged that there was, in fact, not enough connection between the specific performance expectation and the grade-specific standard in the CCSS-M to rely on the preliminary mapping document to establish a link between NGSS and the NAEP mathematics objectives. As a result, the mathematics expert panel (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).[30]

In practice, this meant that a fourth-grade performance expectation in NGSS might be aligned with NAEP at either the fourth-grade level, or at both the fourth and eighth grades. A middle school performance expectation might be aligned with NAEP exclusively at eighth grade, or at both the eighth and twelfth grades.[31] Finally, a high school performance expectation might be aligned exclusively at twelfth grade, or at both eighth and twelfth grades. NAEP objectives at the next higher or lower grade in

[30] The second step involved removing or adding NAEP objectives across grades to the preliminary groupings. The research team leader had the overriding vote in the few cases in which consensus was not reached by the expert panel.

[31] There were no instances of middle school performance expectations involving mathematics judged as aligned with grade 4 NAEP objectives that were not also covered by NAEP grade 8 objectives.

the framework were rated as aligned only if some aspect of the mathematics involved in the NGSS performance expectation was clearly not covered in NAEP objectives at the corresponding grade level. If the panelists judged that a performance expectation did not involve mathematics content or skills described in a NAEP objective at any grade level, it was reported as not being aligned with NAEP.

The outcome of the mathematics comparison ratings was a final set of NAEP mathematics objectives across grades that were grouped and judged as aligned with each NGSS performance expectation, where "aligned" means that the mathematics identified is included in NAEP.

3.3.3 Data analyses

Alignment in mathematics was calculated as the percentage of NGSS performance expectations whose associated practices involved mathematics that was included in NAEP objectives at the corresponding grade level or in two adjacent grades in the 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). Analyses were conducted separately for the NGSS performances expectations in grade 4, middle school, and high school and were also disaggregated by NGSS scientific and engineering practice.

The report also presents qualitative results from the mathematics comparisons based on the expert panel alignment ratings and comments. Content comparison exhibits in appendix G provide detailed content comparisons of NGSS mathematics-related performance expectations and practices and NAEP mathematics framework objectives. The exhibits describe the type of mathematics that may be required on items and tasks developed to assess the NGSS performance expectations and the mathematics expectations of aligned NAEP objectives. The results are organized by mathematics-related practices within each grade level.

3.4 Summary of Key Terms

Exhibit 9 provides descriptions of the key terms that were defined in this section and that are referred to throughout the results in section 4.

Exhibit 9. 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.

4. Results

This section describes the results from the study in four main subsections: (1) science comparisons, (2) TEL comparisons, (3) combined results from across the science and TEL comparisons, and (4) mathematics comparisons. Further divisions within each of these four main subsections begin with a brief description of the relevant tables and then describe the results with the main findings in bold text. All data tables appear at the end of the relevant subsections.

4.1 Science Comparisons

Results from the science comparisons include content overlap, content and grade-level alignment at the objective level, content alignment by NGSS crosscutting concept, alignment at the content area level, practices alignment, and overall framework alignment.

This section also includes detailed content comparisons based on the qualitative content analyses that provide descriptions of the science content in the NGSS performance expectations and NAEP content statements for each content area and grade level (see appendix E). Summaries in exhibits 10-12 in this section highlight specific content similarities and differences between the NGSS and NAEP science framework.

4.1.1 Content overlap

The first set of results describes the content overlap between the NGSS and the NAEP science framework. As described earlier and in exhibit 9, content overlap is the proportion of NGSS and NAEP objectives that were grouped (i.e., judged as covering related content at the corresponding grade level). The results also show the proportion of NGSS and NAEP objectives that were non-grouped (i.e., judged as containing content unique at the corresponding grade level). Results are presented first for the NGSS performance expectations (table 6) and then for the NAEP science content statements (table 7), with each table organized by grade level and content area. The grouped objectives also are disaggregated by whether the expert panel rated them as similar or not similar.

There was substantial content overlap between the NGSS and the NAEP science framework. Overall across grades and content areas, more than three-quarters of the NGSS performance expectations (111 of 136) and more than two-thirds of the NAEP content statements (84.5 of 125)[32] in the sciences were grouped with objectives in the counterpart framework that cover related content at the corresponding grade (see tables 6 and 7).The primary exception was in the comparison of NAEP to the NGSS at grade 4, where the number of grouped NAEP content statements was less than half the number of those that were non-grouped (9.5 compared to 23.5).[33]

[32] Fractional values indicate NAEP content statement(s) that were split but only part of the content statement was grouped with an NGSS performance expectation.

[33] This grade 4 finding relates in part to there being a relatively smaller number of NGSS performance expectations at this single grade in the upper elementary grade band (3-5) compared to the number of grade 4 content statements in NAEP.

Content overlap for the NGSS at grade 4 and middle school was greater than for NAEP at the corresponding grade levels. Nine of 14 NGSS performance expectations at grade 4 and 46 of 55 at the middle school level were grouped. In comparison, 9.5 of 33 NAEP content statements at grade 4 and 32 of 43 at grade 8 were grouped. This indicates that there is relatively more unique content in NAEP at these grade levels. The proportions of grouped objectives in the comparisons of NGSS to NAEP, and vice versa, were more similar at the high school level.

The NGSS had a lower proportion of grouped objectives that were rated as similar than did NAEP. The distribution of NGSS performance expectations between those rated as similar and not similar to NAEP was somewhat comparable in each content area within grades. In contrast, more of the NAEP content statements that were grouped with NGSS performance expectations tended to be rated as similar—at least three times as many were rated similar as not similar at each grade. Since NAEP content statements could be grouped with multiple performance expectations that cover related content, these content statements were more likely to be similar to at least one NGSS performance expectation.

Content overlap was lowest in physical sciences. At the middle and high school levels in both the NGSS and NAEP, the proportion of grouped objectives in physical sciences was smaller than the proportions in life sciences and Earth and space sciences. For example, comparing NAEP to the NGSS, 10 of 16 and 17 of 23 content statements in physical sciences were grouped with NGSS performance expectations at middle and high school, respectively. In contrast, 11 of 12 and 13 of 13 content statements in life sciences and 11 of 15 and 13 of 13 content statements in Earth and space sciences were grouped at middle school and high school, respectively. At grade 4, 4 of 15 NAEP content statements in physical sciences were grouped compared with 2.5 of 7 in life sciences. Comparing the NGSS to NAEP, 4 of 7 performance expectations in physical sciences at grade 4 were grouped, compared with 1 of 2 performance expectations in life sciences and 4 of 5 performance expectations in Earth and space sciences.

4.1.2 Content and grade-level alignment

These results compare the content and grade-level alignment of the NGSS performance expectations with the NAEP content statements and vice versa. They provide data at each grade level (see tables 8-A, 8-B, and 8-C) in three categories: (1) the percentage of objectives that were rated as similar at the corresponding grade—referred to as content alignment; (2) the percentage of objectives that were identified as aligned to content in other grade levels (higher or lower) in the counterpart framework—referred to as grade-level alignment, and (3) the percentage of objectives that were not aligned at any grade in the counterpart framework. As described earlier (see section 3.2.3), the data in category 1 reflect grouped objectives rated as similar at the corresponding grade, whereas the data in category 2 are derived from the panel's identification of alternative groupings at different grade levels for those objectives that were grouped and rated as not similar and those that were non-grouped.

The degree of content alignment varied across the three science content areas. The NGSS and NAEP were the most similar in life sciences. The percentages of grade 4 NGSS performance

expectations that were aligned to NAEP content statements at the corresponding grade ranged from 29 percent (or 2 of 7 performance expectations) in physical sciences to 50 percent (or 1 of 2) in life sciences (see table 8-A). The percentages of NAEP content statements that were aligned to NGSS performance expectations ranged from 13 percent (or 2 of 15) in physical sciences to 36 percent (or 2.5 of 7) in life sciences. Physical sciences thus had the weakest alignment and life sciences had the strongest alignment at grade 4 in both programs, a pattern largely mirrored at the two upper grade levels.

The percentages of middle school NGSS performance expectations that were aligned to NAEP content statements at grade 8 ranged from 42 percent (in physical sciences) to 53 percent (in Earth and space sciences), with 48 percent in life sciences (see table 8-B). From 50 percent of NAEP content statements (in physical science) to 67 percent (in life science) were aligned to NGSS performance expectations at the middle school level.

At the high school level, the percentages of NGSS performance expectations that were aligned to NAEP grade 12 content statements ranged from 42 percent (in physical sciences and Earth and space sciences) to 54 percent (in life sciences) (see table 8-C). From 61 percent of NAEP content statements (in physical sciences) to 81 percent (in life sciences and Earth and space science) were aligned to NGSS performance expectations at the high school level.

The degree of content alignment generally increased with the grade levels. Content alignment between the NGSS and NAEP was low at grade 4, with 36 percent of NGSS performance expectations and 23 percent of NAEP content statements aligned to the counterpart framework at the corresponding grade level.[34] About half of the objectives in the NGSS and NAEP were aligned at grade 8/middle school, with 47 percent of NGSS performance expectations and 56 percent of NAEP content statements aligned with objectives in the counterpart framework at the corresponding grade level. Content alignment was higher for NAEP to NGSS than for NGSS to NAEP at grade 12/high school. Across content areas, 46 percent of NGSS performance expectations in high school were aligned with objectives in the NAEP framework at the corresponding grade level, compared to 71 percent of NAEP grade 12 content statements that were aligned with the NGSS.

The NGSS and NAEP science framework emphasize some content at different grades. 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 to a different grade was low—representing no more than one-fifth of the objectives. The one exception was for NAEP at grade 4, where 59 percent of content statements were aligned at lower or higher grades in the NGSS. The percentage aligned at a different grade decreased over the grade levels for both the NGSS and NAEP.

[34] As described in section 3.1, grade 4 reflects only one grade in the 3-5 grade band in the NGSS, so the NGSS's upper elementary content is somewhat underrepresented in the comparisons. When alternative groupings of NGSS performance expectations from the adjacent grades 3 and 5 were considered (see section 4.3), content alignment with the NAEP grade 4 framework was greater.

At grade 4, some 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). Of the NGSS performance expectations at grade 4, some 21 percent aligned at grade 8 in NAEP.[35]

A smaller percentage of NGSS and NAEP objectives at the middle school and high school level were aligned at a different grade in the other framework. At the middle school level, 16 percent of objectives in NAEP and 9 percent in the NGSS—mostly in physical sciences—aligned at the higher grade in the counterpart framework (grade 12/high school); none aligned at lower grades. In other words, no NGSS performance expectations in middle school were aligned with the NAEP grade 4 content statements, and no NAEP grade 8 content statements were aligned with NGSS performance expectations in grades K-5. At the high school level, relatively few objectives (3 percent of NAEP and 6 percent of NGSS) were aligned at a lower grade in the counterpart framework.

A larger percentage of NGSS performance expectations than NAEP content statements were not aligned at any grade level. At grade 4, some 43 percent of NGSS performance expectations were not aligned at any grade, while only 18 percent of NAEP content statements were not aligned. At middle school/grade 8, some 44 percent of NGSS performance expectations were not aligned at any grade compared to 28 percent of NAEP content statements. At high school/grade 12, some 48 percent of NGSS performance expectations were not aligned at any grade compared to 26 percent of NAEP content statements at grade 12.

For both the NGSS and NAEP and at each grade (except NAEP at grade 4), these rates of non-alignment were greater than the rates of alignment to a higher or lower grade as described previously. This indicates a considerable level of content differences between the two programs across grade levels. In terms of content areas, Earth and space sciences stands out for its unique content: all of the NGSS performance expectations in this area at middle school and nearly all of performance expectations in this area at high school that were not similar at the corresponding grade were not aligned at any grade level. This represents about half of the total Earth and space sciences performance expectations in middle school and high school.

4.1.3 Content alignment by NGSS crosscutting concepts

Tables 9-A, 9-B, 9-C, and 9-D present the distribution of NGSS performance expectations across the seven crosscutting concepts[36] and across the science disciplines in the NGSS overall and at each grade level. The tables also present the extent to which the set of performance expectations in each crosscutting concept was aligned with NAEP content statements.

NGSS performance expectations covered 4 of the 7 crosscutting concepts at grade 4 and all of the crosscutting concepts at the middle and high school levels. The three crosscutting concepts not

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

[36] As described in section 2.2.1 and exhibit 2, crosscutting concepts bridge the different content areas. These are: *patterns*; *cause and effect*; *scale, proportion, and quantity*; *systems and system models*; *energy and matter*; *structure and function*; and *stability and change*. Each NGSS performance expectation is associated with a primary crosscutting concept.

covered by performance expectations at grade 4 were: *scale, proportion, and quantity*; *structure and function*; and *stability and change* (see table 9-A).[37] At each grade level, *cause and effect* was among the most prevalent crosscutting concepts (see tables 9A-C). A total of 29, 27, and 24 percent of NGSS performance expectations in grade 4, middle school, and high school, respectively, were in *cause and effect*.

NGSS performance expectations in certain crosscutting concepts were more commonly associated with certain content areas in the individual grades. For example, all (2 of 2) of the performance expectations in *systems and system models* in grade 4 and over half (8 of 15) in *cause and effect* in middle school were in life sciences. All (4 of 4) of those in *energy and matter* in grade 4 and half (4 of 8) of those in middle school were in physical sciences. At the high school level, however, performance expectations in *energy and matter* were more evenly distributed across the content areas, and the performance expectations that were more concentrated were those (7 of 12) in *stability and change* that were in Earth and space sciences.

Alignment of the NGSS with NAEP varied by crosscutting concept and grade level. Alignment (the percentage of NGSS performance expectations that were similar to NAEP content statements at the corresponding grade level) ranged from 0 to over 80 percent depending on the crosscutting concept and grade level (see below). At least 50 percent of performance expectations in four crosscutting concepts—*energy and matter*, *cause and effect, systems and system models*, and *patterns*—were aligned to NAEP in at least two of three grade levels. In contrast, the crosscutting concepts of *structure and function* and *stability and change* had the lowest alignment across grades (see table 9-D).

At grade 4, half of the performance expectations (5 of 10) in three crosscutting concepts (*cause and effect*, *systems and system models*, and *energy and matter*) were aligned with NAEP content statements at grade 4, while none of those in *patterns* were aligned with NAEP. At middle school, performance expectations in *systems and system models* had the strongest alignment with NAEP content statements at grade 8, with 83 percent (5 of 6) aligned. Conversely, none of the performance expectations in *structure and function* were aligned with NAEP. This is in part due to *structure and function* including the senses and brain processing, which is not included in NAEP (see exhibit 11).

At high school, performance expectations in *patterns* had the strongest alignment with NAEP content statements at grade 12, with 88 percent (7 of 8) aligned. Conversely, the lowest percentage of performance expectations aligned with NAEP was in *systems and system models* (11 percent, or 1 of 9). There were also low percentages of alignment for performance expectations in *structure and function* (33 percent, or 1 of 3) and in *stability and change* (25 percent, or 3 of 12) at the high school level. In

[37] Of the three crosscutting concepts not reflected in the NGSS performance expectations at grade 4, *scale, proportion, and quantity* is covered at grades 3 and 5; the other two (*structure and function* and *stability and change*) are not reflected in performance expectations at any grade in the 3-5 grade band.

part, this may be related to the fact that the NGSS and NAEP vary in the inclusion and treatment of cellular functions and interdependence of organisms across grade levels (see exhibit 12).

Looking across grade levels (see table 9-D), two crosscutting concepts—*patterns* and *energy and matter*—had the strongest alignment with NAEP (with 57 and 54 percent aligned, respectively), followed by *cause and effect* and *scale, proportion, and quantity* (each at about 50 percent aligned). *Structure and function* had the weakest alignment (13 percent), followed by *stability and change* (29 percent).

4.1.4 Alignment at the content area level

Table 10 describes the degree of alignment between the NGSS and NAEP science framework at the overall content area level, drawing on data collected from experts' holistic ratings of content similarity for each content area at each grade level. For each content area and grade level, the table shows the number of panelists assigning each similarity rating and the overall content similarity rating, which is the aggregate measure across all panelists.[38]

At the content area level, alignment between the NGSS and NAEP was stronger at grades 8 and 12 than at grade 4. At grade 4, the overall rating of all three content areas in the NGSS and NAEP was not similar, with all of the panelists rating physical sciences (6 of 6) as not similar and nearly all rating life sciences (4 of 5) and Earth and space sciences (5 of 6) as not similar. In fact, half or more of the panelists rated each of the three content areas in grade 4 in the extreme category: as "substantially or wholly different."

At middle school/grade 8, life sciences and Earth and space sciences received an overall rating of similar in the NGSS and NAEP. Four of six panelists rated these two content areas as "quite similar, but with some differences," and none assigned a rating of "substantially or wholly different." Physical sciences received an overall rating of not similar, although the panel was split, with half the panel assigning a rating of "quite similar but with some differences."

At high school/grade 12, the NGSS and NAEP were rated as similar in life sciences and physical sciences and not similar in Earth and space sciences, with all panelists (6 of 6) agreeing that the latter content area was "quite dissimilar, but with some overlap." No content area at any grade level was rated as "exactly or almost the same" by any panelist.

Life sciences was the only content area to be rated as similar at two of the three grade levels. Life sciences was rated as similar at middle school/grade 8 and high school/grade 12, whereas Earth and space sciences was rated as similar only at middle school/grade 8 and physical sciences only at high school/grade 12. These findings are consistent with the results from the objective level analyses.

[38] As described in sections 3.2.2 and 3.2.3, individual ratings of 3 or 4 are described as "similar" and ratings of 1 or 2 are described as "not similar" in this discussion. Overall content area similarity is an aggregate measure based on at least two-thirds of the panelists rating the overall content area as similar (i.e., by assigning a rating of 3 or 4).

4.1.5 Detailed content comparisons

Exhibits 10-12 summarize the detailed content comparisons for science at grades 4, 8, and 12. They combine quantitative and qualitative data, including content and grade-level alignment results from the expert panel, comments from the expert panel meeting, and a review of the information provided in the framework and supporting documents of both programs. These exhibits identify topics that are covered in the NGSS and NAEP objectives that were rated as aligned, aligned at higher or lower grades, and not aligned, as described in section 4.1.2. The more in-depth exhibits on which these are based can be found in appendix E.

Exhibit 10. Comparing science content in the NGSS and the NAEP framework at grade 4

Overlapping content that is in both the NGSS and NAEP at grade 4 and rated …	
… similar	Forms of energy (heat, sound, light, and electricity) and energy transfer; structures and functions in organisms; effects of weathering and erosion on the Earth's surface and factors affecting erosion; and human use of natural resources (both renewable and non-renewable) and their impact on the environment
… not similar	Features and patterns of waves; and the impact of natural Earth processes on humans
Content that is in the NAEP science framework at grade 4 but is …	
… at a lower grade in the NGSS	Basic properties of light and sound; observing and measuring properties of objects (weight/mass and volume); properties of magnets; basic knowledge of motion and speed; effect of push/pull forces (balanced/unbalanced) on the motion of objects; physical changes caused by heating and cooling (melting, freezing); effects of environmental changes on organisms; life cycles of organisms; introductory concepts of inheritance of physical characteristics; variation of characteristics within species and related advantages in reproduction and survival; Earth materials (rocks, soils, water, air) and their properties that sustain life; the Sun as the source of energy to warm the land, air, and water and to help plants grow; daily and seasonal weather changes; tools for observing and predicting weather; and daily patterns of movement of the Sun and moon
… at a higher grade in the NGSS	Observations and measurements to identify materials based on physical properties including reflectivity, electrical conductivity, and thermal conductivity; introductory concepts relating heat (thermal energy) and temperature; mixtures and pure substances; properties and changes in states of matter (solid, liquid, and gas); effect of the mass of objects on motion; interdependence of organisms; force of Earth's gravity on objects; and the moon's phases and monthly cycle
… not in the NGSS	Descriptions of relative motion based on the positions of different observers
Content that is in the NGSS at grade 4 but is …	
… at a higher grade in NAEP	Relationship between speed and energy; energy changes during collisions; patterns of rock formations and fossils as evidence of changes in Earth's surface over time; and use of topographic maps
… not in NAEP	Using patterns (e.g., sound, digital) to transfer information; and basic knowledge of the senses and information processing by the brain

Exhibit 11. Comparing science content in the NGSS and the NAEP framework at middle school/grade 8

Overlapping content that is in both the NGSS and NAEP at middle school/grade 8 and rated …	
… similar	Composition of matter (atoms, molecules, elements, compounds); particulate model of matter to explain changes of state; evidence of chemical reactions; conservation of matter (atoms) and mass during chemical change; qualitative understanding of Newton's first two laws of motion applied to objects (changes in motion as a result of net force); gravitational force between two masses; forms of potential energy (electric, magnetic, gravitational); energy transfer and conservation; cellular make-up of organisms; essential functions in organisms; organs and organ systems in multicellular organisms; environmental and genetic influences on characteristics and growth of organisms; role of photosynthesis in ecosystems; resource availability and population size; patterns of interactions between organisms in ecosystems; anatomical evidence for relatedness of organisms; natural selection; model of the solar system and the role of gravity to explain cyclic patterns; evidence from rock strata and fossils to measure geologic time and describe Earth's history; geologic processes and evidence of lithospheric plate movement; patterns of atmospheric movement; model to explain convection and regional climates; interpretation of weather maps and diagrams or images of weather systems; and human impacts on the environment
… not similar	Models of molecular structures; electric and magnetic force fields; relationship between temperature, particle motion and thermal energy; waves, their interactions with matter, and energy transfer; cellular functions and organelles; breakdown of food for energy; conservation of matter and flow of energy in ecosystems; impact of environmental changes on populations of organisms; maintaining biodiversity; sexual and asexual reproduction and genetic models; patterns in the fossil record; Earth's water cycle and rock cycle; production of synthetic materials from natural resources; structure of objects in the solar system; global climate change; and impacts of human population growth
Content that is in the NAEP science framework at grade 8 but is …	
… at a lower grade in the NGSS	Conservation of mass during physical change; and waves (types of waves and causes)
… at a higher grade in the NGSS	Arrangement of atoms and molecules to explain properties of chemical substances; chemical properties of elements, including metals; understanding and using the periodic table; velocity versus time graphs; nuclear reactions in the Sun as the source of light energy for photosynthesis; cell differentiation and embryo formation; structure and composition of the Earth's layers; and Earth's magnetic field and its effects
… not in the NGSS	Properties of acids and bases; composition of soil; and composition of the atmosphere
Content that is in the NGSS at middle school but is …	
… at a lower grade in NAEP	Changes in motion determined by the magnitude of forces and the mass of objects; and natural hazards (impacts and prediction)
… at a higher grade in NAEP	Quantitative relationship of kinetic energy to mass and speed of objects; relationship between temperature and the average kinetic energy of particles; effects of genetic mutation; exothermic and endothermic chemical reactions; application of Newton's third law to colliding objects; factors affecting the strength of electric and magnetic forces; and genetic variation and effects of mutation in a population
… not in NAEP	Waves and their applications in digital signals for transmitting information; function of the senses, brain processing, and memory; and the relationship between geoscience processes and Earth's uneven distribution of resources

Exhibit 12. Comparing science content in the NGSS and the NAEP framework at high school/grade 12

Overlapping content that is in both the NGSS and NAEP at high school/grade 12 and rated …	
… similar	Chemical reactivity based on electronic structure of reactants; trends in chemical and physical properties of elements in the periodic table; relating properties of substances to the arrangement and strength of forces between ions, atoms, and molecules; nuclear fission and fusion, including alpha, beta, and gamma particles; the law of conservation of momentum; application of Newton's second and third laws of motion; laws of gravitational and electrical force; kinetic and potential energy of particles; quantitative analysis of the relationship between frequency, wavelength, and velocity of waves; role of DNA in the production of proteins and the relationship between protein structure and cellular function; chemical equations for the photosynthetic process; role of carbon, hydrogen, and oxygen from sugar in formation of amino acids and other essential biomolecules; factors affecting populations and biodiversity in ecosystems; tracing matter and energy flow through trophic levels of ecosystems; complex interactions in ecosystems that maintain stability and impacts of disturbances; genetics concepts, including the role of DNA, chromosomes, and genes; natural selection and evolution, including evidence for common ancestry; evidence for the Big Bang Theory; theories of planet formation and evidence for the age of the solar system and Earth; nuclear processes and the life cycle of stars (including the Sun); theory of plate tectonics; internal and external processes that produce Earth features; variations in energy input and output in Earth systems that impact climate; and models to describe the carbon cycle (including the role of photosynthesis and cellular respiration)
… not similar	Relationship between bond energy, exothermic and endothermic chemical reactions, and conservation of energy; molecular structure and its effect on physical and chemical properties; energy conservation in closed systems; thermal energy and thermal equilibrium; electromagnetic radiation; interaction of objects with electric and magnetic fields; universal force of gravitation; cellular division and differentiation; cellular respiration; recombination and mutation as sources of genetic variation; cycling of matter and flow of energy in ecosystems (aerobic and anaerobic conditions); interactions, feedback, and movement of materials through Earth systems; interactions of humans and natural systems; model of Earth's interior and the cycling of matter by thermal convection; special properties of water and its effects on Earth's features and processes; and coevolution of Earth systems life forms
Content that is in the NAEP science framework at grade 12 but is …	
… at a lower grade in the NGSS	Energy transfer during collisions
… not in the NGSS	Structure of neutral atoms, ions, and isotopes; the nuclear force; and types of motion of particles and macroscopic objects (translation, rotation, and vibration)
Content that is in the NGSS at high school but is …	
… at a lower grade in NAEP	Conservation of atoms and mass during chemical reactions; technological solutions that reduce the impact of human activity on natural systems; causes and effects of global warming; effect of availability of biotic and abiotic resources on populations in an ecosystem; and interacting organ systems in multicellular organisms
… not in NAEP	Effects of temperature and concentration on rates of chemical reactions; chemical equilibrium and the application of Le Chatelier's principle; balancing chemical equations and quantitative analysis of mass conservation; electromagnetic induction; principles of wave behavior and interactions with matter to transmit and capture information and energy; digital transmission of information; concept of homeostasis and feedback mechanisms in organisms; role of group behavior and social interaction on survival of species; economic considerations related to the management of natural resources; sustainability of the human population; and biodiversity

4.1.6 Practices alignment

The results in this section describe the percentage of NGSS performance expectations whose associated scientific and engineering practices[39] were aligned with one of the NAEP science practices (*identifying science principles*, *using science principles*, *using scientific inquiry*, and *using technological design*).[40] Practices alignment indicates to which primary NAEP science practices the NGSS performance expectations were aligned. Table 11 shows the percentage alignment results overall and by grade level and each content area. In tables 12-A-D, results are disaggregated to show the distribution of NGSS performance expectations across the eight scientific and engineering practices and the degree of alignment between the NGSS practices and the NAEP science practices.

Practices alignment by NGSS content domain and grade level

Across grades, all but one of the NGSS performance expectations was aligned with a primary NAEP science practice. The performance expectation that did not have a primary alignment to a NAEP science practice was at the high school level in physical sciences, and this performance expectation was also rated as not similar to the content in the NAEP science framework (see table 11). This means that, overall, the NGSS performance expectations were well within the perceived scope of NAEP's practice requirements.

The majority of NGSS performance expectations were aligned with the NAEP practice of *using science principles*. Fifty-seven, 55, and 64 percent of NGSS performance expectations at grade 4, middle, and high school, respectively, were aligned to NAEP's *using scientific principles*. The next most frequent primary practices alignment (across grades and in nearly all content areas) was *using scientific inquiry*, with 21, 27, and 18 percent of performance expectations aligned to this practice at the three grade levels, respectively. Twenty-one, 11, and 13 percent of performance expectations aligned to the *using technological design* practice at the three grade levels, respectively. In contrast, no performance expectations at grade 4, and very few at the middle and high school levels, mapped to a primary NAEP practice of *identifying science principles*. This is not surprising given that NAEP explicitly includes declarative knowledge in this practice, whereas the NGSS emphasizes the application of science knowledge through the integration of disciplinary core ideas, scientific and engineering practices, and crosscutting concepts.

Additionally, there was some variation by content area. Performance expectations with the strongest alignment to *using technological design* at each grade were more likely to be in physical sciences than in life sciences or Earth and space sciences. The majority of performance expectations with a primary alignment to the least-aligned practice, *identifying science principles*, were in life

[39] The eight NGSS scientific and engineering practices are (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*; and (8) *obtaining, evaluating, and communicating information*.

[40] See exhibit B-2 in appendix B for a description of the general performance expectations in each NAEP science practice.

sciences. One caveat is that the performance expectations being compared to TEL instead of science (i.e., ETS performance expectations in engineering design) would also likely align with *using technological design* in the NAEP science framework if they are applied in a specific context that is covered by the NAEP content statements.

The distribution of NGSS performance expectations across NAEP science practices differed from the NAEP framework's target distribution. At all three grades, the NGSS had a greater emphasis on *using science principles* than the NAEP science framework and very little emphasis on *identifying science principles*. These findings are consistent with the focus in the NGSS on the application of science knowledge.

NGSS performance expectations at grade 4 were distributed across the four NAEP practices as described earlier in this subsection: none in *identifying science principles*, 57 percent in *using science principles*, 21 percent in *using scientific inquiry*, and 21 percent in *using technological design*. NAEP's target percentages at grade 4 for the four science practices are 30, 30, 30, and 10 percent, respectively (see table 1). NGSS performance expectations in middle school were distributed across the four NAEP practices as follows: 7 percent in *identifying science principles*, 55 percent in *using science principles*, 27 percent in *using scientific inquiry*, and 11 percent in *using technological design*. In contrast, NAEP's target percentages at grade 8 are 25, 35, 30, and 10 percent, respectively. The high school performance expectations were distributed across the four NAEP practices as follows: 3 percent in *identifying science principles*, 64 percent in *using science principles*, 18 percent in *using scientific inquiry*, and 13 percent in *using technological* design. In contrast, NAEP's target percentages were 20, 40, 30, and 10 percent, respectively.

Alignment between NGSS scientific and engineering practices and NAEP science practices

NGSS performance expectations covered all (or nearly all) of the NGSS scientific and engineering practices at each grade level. Distribution of the performance expectations across the NGSS scientific and engineering practices varied within and across grades, although two NGSS practices accounted for the highest percentage of performance expectations at all grade levels: *developing and using models* and *constructing explanations and designing solutions* (see tables 12-A-C). The practices of *asking questions and defining problems* and *obtaining, evaluating, and communicating information* were among those with the smallest percentages of performance expectations across grade levels.

At grade 4, the NGSS performance expectations covered seven of the eight NGSS practices (see table 12-A). Performance expectations at grade 4 most frequently required *constructing explanations and designing solutions* (36 percent) and to a lesser extent *developing and using models* (21 percent). The practice not covered at grade 4 was *using mathematics and computational thinking*.[41]

[41] This NGSS practice only had performance expectations at grade 5 in the upper elementary grade band.

At the middle school level, the NGSS performance expectations spanned the full range of NGSS practices, with those requiring *developing and using models* (27 percent) and *constructing explanations and designing solutions* (22 percent) the most prevalent and *asking questions and defining problems* and *using mathematics and computational thinking* the least prevalent (see table 12-B).

At the high school level, the NGSS performance expectations spanned the full range of NGSS practices, and again those requiring *developing and using models* (22 percent) and *constructing explanations and designing solutions* (22 percent) were the most prevalent (see table 12-C). The practice with the least coverage was *asking questions and defining problems*.

NGSS performance expectations in four scientific and engineering practices were aligned most frequently with NAEP's *using science principles*: *developing and using models*, *using mathematics and computational thinking*, *constructing explanations and designing solutions,* and *engaging in argument from evidence*. At each grade level, all of the performance expectations in *developing and using models* were aligned with NAEP's *using science principles.* Across grades, more than half of the performance expectations in *engaging in argument from evidence* and *constructing explanations and designing solutions*, and nearly all in *using mathematics and computational thinking*, were also aligned with NAEP's *using science principles*.[42]

Three NGSS practices were aligned most frequently with NAEP's *using scientific inquiry*: *asking questions and defining problems*; *planning and carrying out investigations*; and *analyzing and interpreting data*. Across grades, most of the performance expectations in *planning and carrying out investigations* and *analyzing and interpreting data* were aligned to NAEP's *using scientific inquiry*. In addition, two middle school performance expectations in *asking questions and defining problems* were also aligned with this NAEP practice. At grade 4 and high school, performance expectations in this NGSS practice were aligned with either NAEP's *identifying science principles* or *using technological design*.[43] About one-third of middle school and high school performance expectations in *engaging in argument from evidence* were also aligned with NAEP's *using scientific inquiry*.

The NGSS practice of constructing explanations and designing solutions also aligned relatively frequently with NAEP's *using technological design.* Across grades, slightly more than one-third (12 of 32) of the performance expectations in the NGSS practice of *constructing explanations and designing solutions* were focused on the engineering aspect of that practice (*designing solutions*) and thus aligned with NAEP's practice of *using technological design*.

[42] There were NGSS performance expectations in the *using mathematics and computational thinking* practice at middle school and high school but not at grade 4.

[43] Performance expectations in only two other NGSS practices mapped to NAEP's *identifying scientific principles* practice: one from *asking questions and defining problems* and one from *constructing explanations and designing solutions*. The former is a high school performance expectation that involves describing the relationship between DNA and inheritance of traits. The latter is a middle school performance expectation that requires knowledge about patterns of interactions among organisms in ecosystems.

4.1.7 Overall framework alignment

These results (table 13) describe the degree of alignment between the NGSS and NAEP science framework overall, drawing on data collected from experts' holistic ratings of overall similarity.[44] For each grade level, the table shows—for content only and for both content and practices together—the number of panelists assigning each similarity rating and the overall framework similarity rating, which is the aggregate measure across all panelists.[45]

In terms of science content only, the NGSS and NAEP frameworks were rated as similar at grades 8 and 12, but not similar at grade 4. At grade 4, half of the panel members (3 of 6) rated the frameworks as "substantially or wholly different," two members rated them as "quite dissimilar, but with some overlap," and one member rated them as "quite similar, but with some differences" (see table 13). This was the only grade in which panel members used either of the extremes of the scale. At middle school/grade 8, all but one panel member (5 of 6) rated the frameworks as "quite similar, but with some differences" for content overall; the dissenting panel member rated them as "quite dissimilar, but with some overlap." At high school/grade 12, there was more of a split in the panel, with two members rating the frameworks as "quite dissimilar, but with some overlap" and four members rating them as "quite similar, but with some differences." These findings confirm the objective-level analyses and content area-level analyses, where all three content areas at grade 4, but just one content area each in grade 8 and 12, were rated as not similar.

The NGSS and NAEP science frameworks were rated as not similar at all grades at the overall framework level when both content and practices were considered together. At grade 4, the rating of not similar was unanimous, with two panel members rating the frameworks "substantially or wholly different" and three panel members rating them as "quite dissimilar but with some overlap." At middle school/grade 8 and high school/grade 12, the number of experts rating the frameworks as similar for content and practices (3 of 5 assigning a rating of 3) was just under the two-thirds threshold for an overall similar rating; none of the panel members used either extremes of the scale.

While these results may seem incongruous with the previously described content and primary practices alignment results, different results are possible since the overall framework rating required the panelists to take both content and practices into account simultaneously. Although the panel assigned a primary NAEP practice that was most closely aligned with each NGSS performance expectation (see table 12-A through 12-D), many of the performance expectations were rated as not similar for content. Additionally, the panelists commented that individual NGSS performance expectations often went beyond what would be expected based on the descriptions of the practices in the NAEP framework if

[44] As described in section 3.2.2, two similarity ratings were provided at the overall framework level, one considering science content only and one considering both content and practices.

[45] Individual ratings of 3 or 4 are described as "similar" and ratings of 1 or 2 are described as "not similar" in this discussion. Overall similarity is an aggregate measure based on at least two-thirds of panelists rating the overall framework as similar (i.e., by assigning a rating of 3 or 4).

applied to a given content statement, even if the science content covered was similar. When considered together, the overall framework ratings were lower than the separate content and practices ratings.

Table 6. Number and type of grouped and non-grouped NGSS science performance expectations, by grade and content area

Grade and content area	Total	Grouped performance expectations		Non-grouped performance expectations
		Similar	Not similar	
Grade 4	14	5	4	5
Physical sciences	7	2	2	3
Life sciences	2	1	0	1
Earth and space sciences	5	2	2	1
Middle school	55	26	20	9
Physical sciences	19	8	6	5
Life sciences	21	10	8	3
Earth and space sciences	15	8	6	1
High school	67	31	25	11
Physical sciences	24	10	8	6
Life sciences	24	13	8	3
Earth and spaces	19	8	9	2
All grades	136	62	49	25
Physical sciences	50	20	16	14
Life sciences	47	24	16	7
Earth and space sciences	39	18	17	4

NOTE: The data indicate the number of NGSS performance expectations that were grouped with one or more NAEP science content statement(s) and those that were not grouped with any NAEP content statement at the corresponding grade level. "Similar" indicates that two-thirds or more of the panelists rated a specific grouping of an NGSS performance expectation with NAEP content statement(s) as similar. Groupings that did not meet this criterion were rated as "not similar."

Table 7. Number and type of grouped and non-grouped NAEP science content statements, by grade and content area

Grade and content area	Total	Grouped NAEP content statements		Non-grouped NAEP content statements
		Similar	Not similar	
Grade 4	33	7.5	2	23.5
Physical science	15	2	2	11
Life science	7	2.5	0	4.5
Earth and space science	11	3	0	8
Grade 8	43	24	8	11
Physical science	16	8	2	6
Life science	12	8	3	1
Earth and space science	15	8	3	4
Grade 12	49	35	8	6
Physical science	23	14	3	6
Life science	13	10.5	2.5	0
Earth and space science	13	10.5	2.5	0
All grades	125	66.5	18	40.5
Physical sciences	54	24	7	23
Life sciences	32	21	5.5	5.5
Earth and space sciences	39	21.5	5.5	12

NOTE: The data indicate the number of NAEP science content statements that were grouped with one or more NGSS performance expectations and those that were not grouped with any NGSS performance expectation at the corresponding grade level. "Similar" indicates that two-thirds or more of the panelists rated a specific grouping of an NGSS performance expectation with NAEP content statement(s) as similar. Groupings that did not meet this criterion were rated as "not similar." Some NAEP content statements were split and mapped to different groupings; each part contributed one-half to the total.

Table 8-A. Content and grade-level alignment between NGSS performance expectations and NAEP science content statements, by content area: Grade 4

Content area	NGSS to NAEP		NAEP to NGSS	
	Number	Percentage	Number[1]	Percentage
(1)	(2)	(3)	(4)	(5)
Physical Sciences	7	100	15.0	100
Similar (at corresponding grade)	2	29	2.0	13
Not similar				
Aligned at a lower grade	†	†	6.0	40
Aligned at a higher grade	2	29	3.0	20
Not aligned	3	43	4.0	27
Life Sciences	2	100	7.0	100
Similar (at corresponding grade)	1	50	2.5	36
Not similar				
Aligned at a lower grade	†	†	3.5	50
Aligned at a higher grade	0	0	1.0	14
Not aligned	1	50	0.0	0
Earth and Space Sciences	5	100	11.0	100
Similar (at corresponding grade)	2	40	3.0	27
Not similar				
Aligned at a lower grade	†	†	6.0	55
Aligned at a higher grade	1	20	0.0	0
Not aligned	2	40	2.0	18
All Content Areas	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

NOTE: See the full notes below table 8-C.

Table 8-B. Content and grade-level alignment between NGSS performance expectations and NAEP science content statements, by content area: Middle school/grade 8

Content Area (1)	NGSS to NAEP Number (2)	NGSS to NAEP Percentage (3)	NAEP to NGSS Number[1] (4)	NAEP to NGSS Percentage (5)
Physical sciences	19	100	16.0	100
Similar (at corresponding grade)	8	42	8.0	50
Not similar				
Aligned at a lower grade	0	0	0.0	0
Aligned at a higher grade	3	16	4.0	25
Not aligned	8	42	4.0	25
Life sciences	21	100	12.0	100
Similar (at corresponding grade)	10	48	8.0	67
Not similar				
Aligned at a lower grade	0	0	0.0	0
Aligned at a higher grade	2	10	1.0	8
Not aligned	9	43	3.0	25
Earth and space sciences	15	100	15.0	100
Similar (at corresponding grade)	8	53	8.0	53
Not similar				
Aligned at a lower grade	0	0	0.0	0
Aligned at a higher grade	0	0	2.0	13
Not aligned	7	47	5.0	33
All content areas	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

NOTE: See the full notes below table 8-C.

Table 8-C. Content and grade-level alignment between NGSS performance expectations and NAEP science content statements, by content area: High school/grade 12

Content area	NGSS to NAEP		NAEP to NGSS	
	Number	Percentage	Number[1]	Percentage
(1)	(2)	(3)	(4)	(5)
Physical sciences	24	100	23.0	100
Similar (at corresponding grade)	10	42	14.0	61
Not similar				
Aligned at a lower grade	1	4	1.0	4
Aligned at a higher grade	†	†	†	†
Not aligned	13	54	8.0	35
Life sciences	24	100	13.0	100
Similar (at corresponding grade)	13	54	10.5	81
Not similar				
Aligned at a lower grade	2	8	0.5	4
Aligned at a higher grade	†	†	†	†
Not aligned	9	38	2.0	15
Earth and space sciences	19	100	13.0	100
Similar (at corresponding grade)	8	42	10.5	81
Not similar				
Aligned at a lower grade	1	5	0.0	0
Aligned at a higher grade	†	†	†	†
Not aligned	10	53	2.5	19
All content areas	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.

NOTE: Content alignment is based on similarity ratings of groupings of NGSS performance expectations (PEs) and NAEP content statement(s) 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 (columns 4 and 5). "Similar (at corresponding grade)" indicates that two-thirds or more of the expert panelists rated a specific grouping as similar (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. 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.

Table 9-A. Alignment of NGSS performance expectations with NAEP science content statements, by crosscutting concept: Grade 4

NGSS crosscutting concept (1)	NGSS performance expectations		Number of performance expectations, by NGSS content domain			Number and percent of performance expectations, by NAEP alignment			
						Similar		Not similar	
	Number (2)	Percent of total (3)	Physical sciences (4)	Life sciences (5)	Earth and space sciences (6)	Number (7)	Percentage (8)	Number (9)	Percentage (10)
Total	14	100	7	2	5	5	36	9	64
1. Patterns	4	29	2	0	2	0	0	4	100
2. Cause and effect: Mechanism and explanation	4	29	1	0	3	2	50	2	50
3. Scale, proportion, and quantity	0	0	0	0	0	0	0	0	0
4. Systems and system models	2	14	0	2	0	1	50	1	50
5. Energy and matter: Flows, cycles, and conservation	4	29	4	0	0	2	50	2	50
6. Structure and function	0	0	0	0	0	0	0	0	0
7. Stability and change	0	0	0	0	0	0	0	0	0

NOTE: See the full notes below table 9-D.

Table 9-B. Alignment of NGSS performance expectations with NAEP science content statements, by crosscutting concept: Middle school

NGSS crosscutting concept (1)	NGSS performance expectations		Number of performance expectations, by NGSS content domain			Number and percent of performance expectations, by NAEP alignment			
						Similar		Not similar	
	Number (2)	Percent of total (3)	Physical sciences (4)	Life sciences (5)	Earth and space sciences (6)	Number (7)	Percentage (8)	Number (9)	Percentage (10)
Total	55	100	19	21	15	26	47	29	53
1. Patterns	9	16	2	4	3	5	56	4	44
2. Cause and effect: Mechanism and explanation	15	27	3	8	4	7	47	8	53
3. Scale, proportion, and quantity	7	13	3	1	3	3	43	4	57
4. Systems and system models	6	11	3	1	2	5	83	1	17
5. Energy and matter: Flows, cycles, and conservation	8	15	4	3	1	4	50	4	50
6. Structure and function	5	9	3	2	0	0	0	5	100
7. Stability and change	5	9	1	2	2	2	40	3	60

NOTE: See the full notes below table 9-D.

Table 9-C. Alignment of NGSS performance expectations with NAEP science content statements, by crosscutting concept: High school

NGSS crosscutting concept (1)	NGSS performance expectations		Number of performance expectations, by NGSS content domain			Number and percent of performance expectations, by NAEP alignment			
						Similar		Not similar	
	Number (2)	Percent of total (3)	Physical sciences (4)	Life sciences (5)	Earth and space sciences (6)	Number (7)	Percentage (8)	Number (9)	Percentage (10)
Total	67	100	24	24	19	31	46	36	54
1. Patterns	8	12	5	2	1	7	88	1	13
2. Cause and effect: Mechanism and explanation	16	24	7	7	2	8	50	8	50
3. Scale, proportion, and quantity	5	7	0	3	2	3	60	2	40
4. Systems and system models	9	13	4	3	2	1	11	8	89
5. Energy and matter: Flows, cycles, and conservation	14	21	5	5	4	8	57	6	43
6. Structure and function	3	4	1	1	1	1	33	2	67
7. Stability and change	12	18	2	3	7	3	25	9	75

NOTE: See the full notes below table 9-D.

Table 9-D. Alignment of NGSS performance expectations with NAEP science content statements, by crosscutting concept: Grade 4, middle school, and high school

NGSS crosscutting concept (1)	NGSS performance expectations		Number of performance expectations, by NGSS content domain			Number and percent of performance expectations, by NAEP alignment			
						Similar		Not similar	
	Number (2)	Percent of total (3)	Physical sciences (4)	Life sciences (5)	Earth and space sciences (6)	Number (7)	Percentage (8)	Number (9)	Percentage (10)
Total	136	100	50	47	39	62	46	74	54
1. Patterns	21	15	9	6	6	12	57	9	43
2. Cause and effect: Mechanism and explanation	35	26	11	15	9	17	49	18	51
3. Scale, proportion, and quantity	12	9	3	4	5	6	50	6	50
4. Systems and system models	17	13	7	6	4	7	41	10	59
5. Energy and matter: Flows, cycles, and conservation	26	19	13	8	5	14	54	12	46
6. Structure and function	8	6	4	3	1	1	13	7	88
7. Stability and change	17	13	3	5	9	5	29	12	71

NOTE: Columns 2 and 3 include the number and percentage of NGSS performance expectations in each crosscutting concept. Columns 4 through 6 display the number of these performance expectations in each of the NGSS content domains. Columns 7 through 10 include the number and percentage of performance expectations in each crosscutting concept that were judged as similar or not similar to any NAEP content statement. "Similar" indicates that performance expectations were judged by two-thirds or more of panelists as being similar to one or more NAEP content statement(s) in physical sciences, life sciences, or Earth and space sciences at the corresponding grade level. Detail may not sum to totals because of rounding.

Table 10. Content alignment between the NGSS and NAEP science framework at the content area level, by grade and content area

Grade and content area	Number of panelists assigning each similarity rating: "Substantially or wholly different" (Rating 1)	"Quite dissimilar, but with some overlap" (Rating 2)	"Quite similar, but with some differences" (Rating 3)	"Exactly or almost the same" (Rating 4)	Overall content area similarity
Grade 4					
Physical sciences	4	2	0	0	Not similar
Life sciences	3	1	1	0	Not similar
Earth and space sciences	4	1	1	0	Not similar
Middle school/grade 8					
Physical sciences	0	3	3	0	Not similar
Life sciences	0	2	4	0	Similar
Earth and space sciences	0	2	4	0	Similar
High school/grade 12					
Physical sciences	0	2	4	0	Similar
Life sciences	0	2	4	0	Similar
Earth and space sciences	0	6	0	0	Not similar

NOTE: Content area ratings were assigned after the expert panel completed their ratings of each NGSS performance expectation and NAEP content statement in that content area. An overall content area rating of "similar" indicates that at least two-thirds of panelists rated the content area as similar (rating 3 or 4). One panelist did not provide an overall content area rating for life sciences at grade 4.

Table 11. Alignment of NGSS performance expectations (PEs) with NAEP science practices, by grade and content area

Grade and content area	NGSS PEs aligned with a primary NAEP science practice								NGSS PEs not aligned with a primary NAEP science practice		Total	
	Identifying science principles		Using science principles		Using scientific inquiry		Using technological design					
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Grade 4	0	0	8	57	3	21	3	21	0	0	14	100
Physical sciences	0	0	5	71	0	0	2	29	0	0	7	100
Life sciences	0	0	2	100	0	0	0	0	0	0	2	100
Earth and space sciences	0	0	1	20	3	60	1	20	0	0	5	100
Middle school	4	7	30	55	15	27	6	11	0	0	55	100
Physical sciences	1	5	10	53	5	26	3	16	0	0	19	100
Life sciences	3	14	12	57	5	24	1	5	0	0	21	100
Earth and space sciences	0	0	8	53	5	33	2	13	0	0	15	100
High school	2	3	43	64	12	18	9	13	1	1	67	100
Physical sciences	0	0	14	58	4	17	5	21	1	4	24	100
Life sciences	2	8	16	67	4	17	2	8	0	0	24	100
Earth and space sciences	0	0	13	68	4	21	2	11	0	0	19	100
All grades	6	4	81	60	30	22	18	13	1	1	136	100
Physical sciences	1	2	29	58	9	18	10	20	1	2	50	100
Life sciences	5	11	30	64	9	19	3	6	0	0	47	100
Earth and space sciences	0	0	22	56	12	31	5	13	0	0	39	100

NOTE: The data indicate the number and percentage of NGSS performance expectations in the science disciplines judged by panelists as being aligned with a primary NAEP science practice. The primary practice was determined as the NAEP science practice most frequently identified as primary, provided that at least three panelists agreed. "NGSS PEs not aligned with a primary NAEP practice" indicates that the panel was not able to determine a primary NAEP practice. Detail may not sum to totals because of rounding.

Table 12-A. Alignment between NGSS scientific and engineering practices and NAEP science practices: Grade 4

NGSS scientific and engineering practices	NGSS performance expectations		Number aligned with a primary NAEP practice				Not aligned with a primary NAEP practice
	Number	Percentage	Identifying science principles	Using science principles	Using scientific inquiry	Using technological design	
Total	14	100	0	8	3	3	0
Percent of total, by NAEP science practice	†	†	0	57	21	21	0
1. Asking questions and defining problems	1	7	0	1	0	0	0
2. Developing and using models	3	21	0	3	0	0	0
3. Planning and carrying out investigations	2	14	0	1	1	0	0
4. Analyzing and interpreting data	1	7	0	0	1	0	0
5. Using mathematics and computational thinking	0	0	0	0	0	0	0
6. Constructing explanations and designing solutions	5	36	0	1	1	3	0
7. Engaging in argument from evidence	1	7	0	1	0	0	0
8. Obtaining, evaluating, and communicating information	1	7	0	1	0	0	0

NOTE: See the full notes below table 12-D.

Table 12-B. Alignment between NGSS scientific and engineering practices and NAEP science practices: Middle school

NGSS scientific and engineering practices	NGSS performance expectations		Number aligned with a primary NAEP practice				Not aligned with a primary NAEP practice
	Number	Percentage	Identifying science principles	Using science principles	Using scientific inquiry	Using technological design	
Total	55	100	4	30	15	6	0
Percent of total, by NAEP science practice	†	†	7	55	27	11	0
1. Asking questions and defining problems	2	4	0	0	2	0	0
2. Developing and using models	15	27	0	15	0	0	0
3. Planning and carrying out investigations	5	9	0	0	5	0	0
4. Analyzing and interpreting data	8	15	0	1	6	1	0
5. Using mathematics and computational thinking	2	4	0	2	0	0	0
6. Constructing explanations and designing solutions	12	22	1	7	0	4	0
7. Engaging in argument from evidence	7	13	0	4	2	1	0
8. Obtaining, evaluating, and communicating information	4	7	3	1	0	0	0

NOTE: See the full notes below table 12-D.

Table 12-C. Alignment between NGSS scientific and engineering practices and NAEP science practices: High school

NGSS scientific and engineering practices	NGSS performance expectations		Number aligned with a primary NAEP practice				Not aligned with a primary NAEP practice
	Number	Percentage	Identifying science principles	Using science principles	Using scientific inquiry	Using technological design	
Total	67	100	2	43	12	9	1
Percent of total, by NAEP science practice	†	†	3	64	18	13	1
1. Asking questions and defining problems	2	3	1	0	0	1	0
2. Developing and using models	15	22	0	15	0	0	0
3. Planning and carrying out investigations	5	7	0	0	5	0	0
4. Analyzing and interpreting data	5	7	0	2	3	0	0
5. Using mathematics and computational thinking	12	18	0	10	1	1	0
6. Constructing explanations and designing solutions	15	22	0	10	0	5	0
7. Engaging in argument from evidence	8	12	0	4	3	1	0
8. Obtaining, evaluating, and communicating information	5	7	1	2	0	1	1

NOTE: See the full notes below table 12-D.

Table 12-D. Alignment between NGSS scientific and engineering practices and NAEP science practices: Grade 4, middle school, and high school

NGSS scientific and engineering practices	NGSS performance expectations		Number aligned with a primary NAEP practice				Not aligned with a primary NAEP practice
	Number	Percentage	Identifying science principles	Using science principles	Using scientific inquiry	Using technological design	
Total	136	100	6	81	30	18	1
Percent of total, by NAEP science practice	†	†	4	60	22	13	1
1. Asking questions and defining problems	5	4	1	1	2	1	0
2. Developing and using models	33	24	0	33	0	0	0
3. Planning and carrying out investigations	12	9	0	1	11	0	0
4. Analyzing and interpreting data	14	10	0	3	10	1	0
5. Using mathematics and computational thinking	14	10	0	12	1	1	0
6. Constructing explanations and designing solutions	32	24	1	18	1	12	0
7. Engaging in argument from evidence	16	12	0	9	5	2	0
8. Obtaining, evaluating, and communicating information	10	7	4	4	0	1	1

† Not applicable.

NOTE: The primary NAEP science practice was determined as the practice most frequently identified by panelists as aligned, provided that at least three panelists agreed. Detail may not sum to totals because of rounding.

Table 13. Alignment between the NGSS and NAEP science at the overall framework level, by grade

Grade	Number of panelists assigning each similarity rating				Overall framework similarity
	"Substantially or wholly different" (Rating 1)	"Quite dissimilar, but with some overlap" (Rating 2)	"Quite similar, but with some differences" (Rating 3)	"Exactly or almost the same" (Rating 4)	
Grade 4					
Content only	3	2	1	0	Not similar
Content and practices	2	3	0	0	Not similar
Middle school/grade 8					
Content only	0	1	5	0	Similar
Content and practices	0	2	3	0	Not similar
High school/grade 12					
Content only	0	2	4	0	Similar
Content and practices	0	2	3	0	Not similar

NOTE: Overall framework ratings were assigned after the expert panel completed their ratings of NGSS performance expectations and NAEP content statements across all content areas. Raters were asked to provide two separate ratings at each grade level, using a 4-point scale. For the first rating, "content only," the panel considered only the similarity of science content covered in NGSS and the NAEP science framework. For the second rating, "content and practices," the panel considered the coverage of both content and science practices. A summary rating of "similar" indicates that at least two-thirds of panelists rated the overall framework as similar (rating 3 or 4). One panelist did not provide ratings for content and practices.

4.2 TEL Comparisons

The results from the TEL comparisons include content overlap, content alignment, and practices alignment. The comparisons of the NGSS to NAEP TEL are disaggregated by grade and by the two types of NGSS performance expectations in engineering, technology, and applications of science (ETS): (1) those in engineering design and (2) those in the natural sciences (physical, life, and Earth and space sciences) with connections to ETS. The comparisons of NAEP TEL to the NGSS are disaggregated by grade and by TEL assessment areas: design and systems, technology and society, and information and communication technology.

This section also includes detailed content comparisons based on the qualitative analyses of the specific content covered in the NGSS performance expectations in the ETS discipline and the NAEP TEL framework assessment targets at each grade level (see appendix F). The summary in exhibit 13 in this section highlights specific content that is similar and different in the NGSS and the NAEP TEL framework.

4.2.1 Content overlap

The first set of results describes the content overlap between the NGSS and the NAEP TEL framework. As with science, content overlap is described by the proportion of NGSS and NAEP objectives that were grouped (i.e., judged as covering related content at the corresponding grade level). The results also show the proportion of NGSS and NAEP objectives that were non-grouped (i.e., judged as containing content unique at the corresponding grade level). The results are presented first for the

NGSS (table 14) and then for NAEP (table 15), with each table organized by grade level and NGSS content domain or TEL assessment area. The grouped objectives also are disaggregated by whether the expert panel rated the grouping as similar or not similar.

Much of the NGSS's content in engineering, technology, and applications of science (ETS) overlaps content in the NAEP TEL framework. All of the performance expectations in the 3-5 grade band were grouped with NAEP TEL assessment targets, as were nearly three-quarters of those at the middle school level and nearly two-thirds of those at the high school level (see table 14). However, there were some differences by type of ETS performance expectation. At each of the three grade levels, all of the NGSS performance expectations in engineering design were grouped with assessment targets in NAEP TEL. Similarly, at the 3-5 grade band, all of the performance expectations in science with connections to ETS were grouped with NAEP TEL assessment targets. At the upper grade levels, however, there were lower numbers (and proportions) of science performance expectations with connections to ETS that were grouped, particularly in Earth and space sciences.

In contrast, NAEP TEL covers a much broader range of content than do the NGSS performance expectations in ETS. There are many more assessment targets in NAEP TEL than NGSS performance expectations in ETS. In addition, there are some NAEP TEL assessment areas or subareas that do not have corresponding disciplinary core or component ideas in the NGSS. No more than 14 of the 47 assessment targets in each grade were grouped with NGSS performance expectations compared to 39, 37, and 33 assessment targets that were non-grouped at grades 4, 8, and 12, respectively (see table 15). There were some differences by assessment area, however, with assessment targets in design and systems more likely to be grouped than those in the other assessment areas. The one exception was grade 12, where similar numbers of assessment targets were grouped in all three assessment areas.

4.2.2 Content alignment

Tables 16 and 17 describe the content alignment between the NGSS and NAEP TEL framework (i.e., the percentage of NGSS and NAEP objectives rated as similar at the corresponding grade in the counterpart framework). The tables also show the percentages rated as not similar.

The NGSS and NAEP TEL framework were most closely aligned in the area of engineering design across the three grade levels. All NGSS performance expectations in engineering design at grades 3-5 and three-quarters in middle school and high school were aligned to NAEP TEL assessment targets at the corresponding grades (see table 16), as were the majority of science performance expectations that involve design applications. These performance expectations were generally aligned with the TEL engineering design subarea of design and systems.

Alignment of the NGSS with the NAEP TEL framework was lower for performance expectations in the sciences with connections to ETS, especially at the middle and high school levels. More than half of the science performance expectations in ETS 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. In contrast, at the 3-5 grade band, 75 percent of performance expectations in the sciences with connections to ETS were aligned with NAEP TEL at the corresponding grade.

The alignment of NAEP TEL with the NGSS was relatively weak at all three grade levels. The strongest alignment was in design and systems (at grades 4 and 8) and technology and society (at grade 12), but this reflected only about one-third of assessment targets in these areas. There was essentially no alignment of NAEP assessment targets in information and communication technology (ICT), with the exception of three assessment targets at grade 12 (see table 17).

At grade 4, less than one-third (32 percent) of the assessment targets in design and systems and none of those in ICT or technology and society were rated as similar to the NGSS at the corresponding grade level. Alignment was higher at grades 8 and 12, but still generally low. At grade 8, again none of the assessment targets in ICT were aligned with the NGSS at the corresponding grade level, and alignment was also low in technology and society (13 percent). The greatest degree of alignment was in design and systems (32 percent). At grade 12, alignment to the NGSS ranged from 23 percent of the assessment targets in ICT to 33 percent of the targets in technology and society. The degree of alignment in design and systems at grade 12 (26 percent) was slightly lower than that at either of the lower grades (32 percent).

Exhibit 13. Comparing engineering and technology content of the NGSS and NAEP TEL frameworks

Overlapping content that is in both the NGSS and NAEP TEL framework and is rated …	
… similar at grade 4[1]	Identifying design criteria and constraints; generating and comparing multiple design solutions; and developing and testing models, including gathering data to improve design
… similar at grade 8	Objectives above applied at a level appropriate to grade 8 with more focus on evaluating competing design solutions to meet criteria and constraints; using iterative testing to optimize the design solution; and considering the impact of humans and technology on the environment
… similar at grade 12	Objectives above applied at a level appropriate to grade 12 with a focus on applying these skills to analyze global challenges, understand impacts of human activity and technology on society and the environment, and address complex, real-world problems; and on using models and computer simulations to examine interactions within and between systems
… not similar at the corresponding grade	Impacts of technology on the environment (grade 4); impact of the use of natural resources to produce synthetic materials (grade 8); and methods for refining design solutions and their application to technological devices (grade 12)
Content that is in NAEP TEL but not in the NGSS[2] *…*	
	Nature of technology; technological systems and subsystems; maintenance and troubleshooting; impact of new technologies on different societies; information and communication technologies; ethics, equity, and responsibility; and collaboration and communication
Content that is in the NGSS but not in NAEP TEL …	
	Objectives that require knowledge of specific science content and technology such as analyzing and interpreting data to determine scale properties of objects in the solar system (grade 8) and constructing an explanation of the Big Bang Theory based on various pieces of evidence obtained using advanced technology (grade 12)

[1] These descriptions are given in terms of NAEP grade levels 4, 8, and 12, which for the TEL comparisons correspond to the 3-5, middle school, and high school grade bands in the NGSS, respectively.

[2] While the concepts and skills in these areas may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there are no specific performance expectations in the NGSS at the corresponding grade level that explicitly require them.

NOTE: See exhibits F-1, F-2, and F-3 in appendix F for additional detail at grades 4, 8, and 12, respectively.

4.2.3 Practices alignment

These results describe the percentage of NGSS performance expectations in ETS whose associated practices were aligned with one of the NAEP TEL practices (*understanding technological principles*, *developing solutions and achieving goals*, and *communicating and collaborating*).[46] Practices alignment indicates to which primary NAEP TEL practices the NGSS performance expectations were aligned.

Table 18 shows the percentage alignment results overall and by grade and NGSS disciplinary area (engineering design and science with connections to ETS). In tables 19-A-D, results are disaggregated to show the distribution of NGSS performance expectations across the eight scientific and engineering practices and the degree of alignment between the NGSS practices and the NAEP TEL practices at each grade level and overall.

[46] See exhibit B-4 in appendix B for a description of the general performance expectations in each NAEP TEL practice.

Practices alignment by NGSS content domain and grade level

All of the NGSS ETS performance expectations in the 3-5 grade band were aligned with a primary NAEP technology and engineering practice, as were the majority of those at the middle and high school levels. Three performance expectations at the middle school level and five at the high school level were not aligned with a primary NAEP technology and engineering practice (see table 18). These were all science performance expectations with connections to ETS that were also rated as not similar to the content in any NAEP TEL assessment target. With these exceptions, however, the NGSS ETS performance expectations were well within the perceived scope of NAEP technology and engineering practice requirements.

The NGSS performance expectations in ETS did not cover the full range of practices described in the NAEP TEL framework. Eighty-one percent of the performance expectations in ETS across grades were aligned with a primary NAEP TEL practice, with the percentages by grade ranging from 75 percent (at the high school level) to 100 percent (in the 3-5 grade band). However, of those that were aligned, at least three-quarters (26 of 34) across all grade bands 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*).

All of the NGSS performance expectations in engineering design were aligned with NAEP's *developing solutions and achieving goals* whereas the alignment of performance expectations in the sciences with connections to ETS varied across the NAEP practices. All 11 performance expectations in engineering design—three in the 3-5 grade band and four each at the middle school, and high school levels—were aligned with NAEP's *developing solutions and achieving goals*. In the 3-5 grade band, three of the four performance expectations in science with connections to ETS also were aligned with this NAEP practice, with the one remaining performance expectation in science aligned with *understanding technological principles*.

At the two upper grade levels, there was more variation. At the middle school level, 45 percent (5 of 11) of performance expectations in science with connections to ETS were aligned with *developing solutions and achieving goals*, and 27 percent (or 3 of 11) were aligned with *understanding technological principles*. The remaining three performance expectations were not aligned with any NAEP TEL practice. At the high school level, 44 percent (7 of 16) of the NGSS science performance expectations with connections to ETS were aligned with *developing solutions and achieving goals*, 6 percent (1 of 16) were aligned with *understanding technological principles*, and 19 percent (3 of 16) were aligned with NAEP's *communicating and collaborating*. High school was the only grade level with performance expectations aligned with *communicating and collaborating*; these performance expectations require communicating scientific and technical information about the functioning of designed materials, technological devices, and human impact. The remaining 31 percent of performance expectations (5 of 16) in high school were not aligned with any NAEP TEL practice.

Alignment between NGSS scientific and engineering practices and NAEP TEL practices

The NGSS performance expectations in ETS covered most, but not all, of the eight NGSS scientific and engineering practices, with different sets of practices covered at different grades. In the 3-5 grade band, there were seven NGSS ETS performance expectations and they covered four of the NGSS scientific and engineering practices, with four in *constructing explanations and designing solutions* and one each in *asking questions and defining problems*; *planning and carrying out investigations*; and *obtaining, evaluating, and communicating information* (see table 19-A). There were no NGSS ETS performance expectations that required the practices of *developing and using models*; *analyzing and interpreting data*; *using mathematics and computational thinking*; or *engaging in argument from evidence*. At the middle school level, there were 15 NGSS performance expectations in ETS and they covered seven of the NGSS scientific and engineering practices, excluding only *using mathematics and computational thinking* (see table 19-B). At the high school level, there were 20 NGSS performance expectations in ETS that covered seven of the NGSS scientific and engineering practices, excluding only *planning and carrying out investigations* (see table 19-C).

Half of the NGSS performance expectations in ETS were in the two practices that had engineering-specific components: *asking questions and defining problems* and *constructing explanations and designing solutions*. Across all grades, 21 of 42 ETS performance expectations were from the two practices with engineering-specific aspects (i.e., "defining problems" from the first and "designing solutions" from the second) (see table 19-D). The level of relative emphasis on these two practices was greatest at grades 3-5 (71 percent, or 5 of 7) and least at the middle school level (33 percent, or 5 of 15), with the high school level at 55 percent (11 of 20) of performance expectations requiring these two practices.

NGSS performance expectations in five scientific and engineering practices were aligned exclusively with NAEP's *developing solutions and achieving goals*. The five NGSS practices aligned exclusively to NAEP's *developing solutions and achieving goals* were *developing and using models*, *planning and carrying out investigations*, *analyzing and interpreting data*, *constructing explanations and designing solutions*, and *engaging in argument from evidence*. The number of performance expectations in each of these practices was generally small (from one to three), with the exception of *constructing explanations and designing solutions*, in which all 15 of the performance expectations across grades that were aligned were in NAEP's *developing solutions and achieving goals*. Performance expectations in *asking questions and defining problems* and *using mathematics and computational thinking* were aligned to multiple NAEP practices.

NGSS performance expectations in the practice of *obtaining, communicating, and evaluating information* were aligned most frequently with the NAEP TEL practice of *understanding technological principles*. In the 3-5 and middle school grade bands, NGSS performance expectations in *obtaining, evaluating, and communicating information* were aligned exclusively with this NAEP TEL practice (one in grades 3-5 and three in middle school). The two NGSS performance expectations at the high school level in *obtaining, evaluating, and communicating information*, however, were aligned with

the NAEP TEL practice of *communicating and collaborating*, two of only three NGSS performance expectations across all grade levels to do so.

The NGSS practices associated with performance expectations that did not map to any NAEP TEL practice varied across grades. The performance expectations that did not map to a primary NAEP TEL practice were split across three NGSS practices at the middle school level: *planning and carrying out investigations*, *analyzing and interpreting data*, and *engaging in argument from evidence*. At the high school level, two of the five performance expectations that did not map to a NAEP practice were in *constructing explanations and designing solutions* and the other three were split across three NGSS practices: *developing and using models*, *analyzing and interpreting data*, and *using mathematics and computational thinking*. *Analyzing and interpreting data* was the only NGSS practice in which there were no performance expectations that aligned with a NAEP TEL practice at either the middle or high school levels. Again, all of the performance expectations that were not aligned with a NAEP TEL practice were from the science disciplines with connections to ETS and were also rated as not similar to the content in the TEL assessment targets. There were no performance expectations in the 3-5 grade band that were not aligned with a NAEP TEL practice.

Table 14. Number and type of grouped and non-grouped NGSS performance expectations in engineering, technology, and applications of science (ETS), by grade band and content domain

Grade band and content domain	Total	Grouped performance expectations		Non-grouped performance expectations
		Similar	Not similar	
Grades 3-5[1]	7	6	1	0
Engineering design	3	3	0	0
Science – with connections to ETS				
Physical sciences	2	2	0	0
Life sciences	0	0	0	0
Earth and space sciences	2	1	1	0
Middle school	15	8	3	4
Engineering design	4	3	1	0
Science – with connections to ETS				
Physical sciences	5	3	1	1
Life sciences	3	1	1	1
Earth and space sciences	3	1	0	2
High school	20	9	4	7
Engineering design	4	3	1	0
Science – with connections to ETS				
Physical sciences	6	1	3	2
Life sciences	2	2	0	0
Earth and space sciences	8	3	0	5
All grades	42	23	8	11
Engineering design	11	9	2	0
Science – with connections to ETS				
Physical sciences	13	6	4	3
Life sciences	5	3	1	1
Earth and space sciences	13	5	1	7

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

NOTE: The date in the table indicate the number of NGSS performance expectations in engineering, technology, and applications of science (ETS) that were grouped with one or more NAEP TEL assessment target(s) and those that were not grouped with any TEL assessment target at the corresponding grade level. Data are shown separately for NGSS performance expectations from "Engineering Design" (at the 3-5, middle school, and high school grade bands) and for performance expectations from the science disciplines (in grade 4, middle school, and high school). "Similar" indicates that two-thirds or more of the panelists rated a specific grouping of NGSS performance expectation with NAEP TEL assessment target(s) as similar. Groupings that did not meet this criterion were rated as "not similar."

Table 15. Number and type of grouped and non-grouped NAEP TEL assessment targets, by grade and assessment area

Grade and assessment area	Total	Grouped NAEP TEL Targets		Non-grouped NAEP TEL targets
		Similar	Not similar	
Grade 4	47	6	2	39
Design and systems	19	6	0	13
Technology and society	15	0	2	13
Information and communication technology	13	0	0	13
Grade 8	47	8	2	37
Design and systems	19	6	1	12
Technology and society	15	2	1	12
Information and communication technology	13	0	0	13
Grade 12	47	13	1	33
Design and systems	19	5	0	14
Technology and society	15	5	0	10
Information and communication technology	13	3	1	9
All grades	141	27	5	109
Design and systems	57	17	1	39
Technology and society	45	7	3	35
Information and communication technology	39	3	1	35

NOTE: The data in the table indicate the number of NAEP TEL assessment targets that were grouped with one or more NGSS performance expectation(s) and those that were not grouped with any NGSS performance expectation at the corresponding grade level. "Similar" indicates that two-thirds or more of the panelists rated a grouping of TEL assessment target(s) with NGSS performance expectation as similar. Grouped TEL targets that did not meet this criterion were rated as "not similar."

Table 16. Content alignment of NGSS performance expectations in engineering, technology, and applications of science (ETS) and 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 ETS, as well as overall across both content domains. Detail may not sum to totals because of rounding.

Table 17. Content alignment of NAEP TEL assessment targets with NGSS performance expectations in engineering, technology, and applications of Science (ETS), by grade and assessment area

	NAEP TEL assessment targets Aligned with NGSS performance expectations					
	Grade 4		Grade 8		Grade 12	
Assessment area	Number	Percentage	Number	Percentage	Number	Percentage
Design and systems	19	100	19	100	19	100
Similar	6	32	6	32	5	26
Not similar	13	68	13	68	14	74
Technology and society	15	100	15	100	15	100
Similar	0	0	2	13	5	33
Not similar	15	100	13	87	10	67
Information and communication technology	13	100	13	100	13	100
Similar	0	0	0	0	3	23
Not similar	13	100	13	100	10	77
All assessment areas	47	100	47	100	47	100
Similar	6	13	8	17	13	28
Not similar	41	87	39	83	34	72

NOTE: Content alignment is based on similarity ratings of groupings of NAEP TEL assessment targets and NGSS performance expectations (PEs) with corresponding 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 panelists rated a specific grouping of NAEP assessment target(s) and NGSS PEs at the corresponding grade level as similar by assigning a rating of 3 or 4. NAEP assessment targets may be mapped to multiple groupings, but each NGSS PE maps to a single grouping. In cases where an individual NAEP assessment target was mapped to multiple NGSS PEs, the NAEP assessment target was rated "similar" if two-thirds of the panelists considered it to be similar to at least one NGSS performance expectation. "Not similar" includes groupings that were not rated as "similar" by at least two-thirds of the panelists as well as NAEP assessment targets that were not grouped with any NGSS PE. Detail may not sum to totals because of rounding.

Table 18. Alignment of NGSS performance expectations (PEs) in engineering, technology, and applications of science (ETS) with NAEP TEL practices, by grade band and content domain

	NGSS PEs aligned with a primary NAEP TEL practice						NGSS PEs not aligned with a primary NAEP TEL practice		Total	
	Understanding technological principles		Developing solutions and achieving goals		Communicating and collaborating					
Grade band and content domain	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Grades 3-5[1]	1	14	6	86	0	0	0	0	7	100
Engineering design	0	0	3	100	0	0	0	0	3	100
Science - with connections to ETS	1	25	3	75	0	0	0	0	4	100
Middle school	3	20	9	60	0	0	3	20	15	100
Engineering design	0	0	4	100	0	0	0	0	4	100
Science - with connections to ETS	3	27	5	45	0	0	3	27	11	100
High school	1	5	11	55	3	15	5	25	20	100
Engineering design	0	0	4	100	0	0	0	0	4	100
Science - with connections to ETS	1	6	7	44	3	19	5	31	16	100
All grades	5	12	26	62	3	7	8	19	42	100
Engineering design	0	0	11	100	0	0	0	0	11	100
Science - with connections to ETS	5	16	15	48	3	10	8	26	31	100

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

NOTE: The data in the table indicate the number and percentage of NGSS performance expectations in ETS that were judged by panelists as being aligned with a primary NAEP TEL practice. The primary practice was determined as the NAEP TEL practice most frequently identified as primary by panelists as aligned, provided that at least three panelists agreed. "NGSS PEs not aligned with a primary NAEP TEL practice" indicates that the panel was not able to determine a primary NAEP practice. Data are shown separately for NGSS performance expectations from "engineering design" and performance expectations from the science disciplines with connections to ETS. Detail may not sum to totals because of rounding.

Table 19-A. Alignment between NGSS scientific and engineering practices and NAEP TEL practices: Grades 3-5

NGSS scientific and engineering practices	NGSS performance expectations		Number aligned with each NAEP TEL practice			No primary alignment
	Number	Percentage	Understanding technological principles	Developing solutions and achieving goals	Communicating and collaborating	
Total	7	100	1	6	0	0
Percent of total, by NAEP TEL practice	†	†	14	86	0	0
1. Asking questions and defining problems	1	14	0	1	0	0
2. Developing and using models	0	0	0	0	0	0
3. Planning and carrying out investigations	1	14	0	1	0	0
4. Analyzing and interpreting data	0	0	0	0	0	0
5. Using mathematics and computational thinking	0	0	0	0	0	0
6. Constructing explanations and designing solutions	4	57	0	4	0	0
7. Engaging in argument from evidence	0	0	0	0	0	0
8. Obtaining, evaluating, and communicating information	1	14	1	0	0	0

NOTE: See the full notes below table 19-D.

Table 19-B. Alignment between NGSS scientific and engineering practices and NAEP TEL practices: Middle school

NGSS scientific and engineering practices	NGSS performance expectations		Number aligned with each NAEP TEL practice			No primary alignment
	Number	Percentage	Understanding technological principles	Developing solutions and achieving goals	Communicating and collaborating	
Total	15	100	3	9	0	3
Percent of total, by NAEP TEL practice	†	†	20	60	0	20
1. Asking questions and defining problems	1	7	0	1	0	0
2. Developing and using models	1	7	0	1	0	0
3. Planning and carrying out investigations	1	7	0	0	0	1
4. Analyzing and interpreting data	2	13	0	1	0	1
5. Using mathematics and computational thinking	0	0	0	0	0	0
6. Constructing explanations and designing solutions	4	27	0	4	0	0
7. Engaging in argument from evidence	3	20	0	2	0	1
8. Obtaining, evaluating, and communicating information	3	20	3	0	0	0

NOTE: See the full notes below table 19-D.

Table 19-C. Alignment between NGSS scientific and engineering practices and NAEP TEL practices: High school

NGSS scientific and engineering practices	NGSS performance expectations		Number aligned with each NAEP TEL practice			
	Number	Percentage	Understanding technological principles	Developing solutions and achieving goals	Communicating and collaborating	No primary alignment
Total	20	100	1	11	3	5
Percent of total, by NAEP TEL practice	†	†	5	55	15	25
1. Asking questions and defining problems	2	10	1	1	0	0
2. Developing and using models	1	5	0	0	0	1
3. Planning and carrying out investigations	0	0	0	0	0	0
4. Analyzing and interpreting data	1	5	0	0	0	1
5. Using mathematics and computational thinking	4	20	0	2	1	1
6. Constructing explanations and designing solutions	9	45	0	7	0	2
7. Engaging in argument from evidence	1	5	0	1	0	0
8. Obtaining, evaluating, and communicating information	2	10	0	0	2	0

NOTE: See the full notes below table 19-D.

Table 19-D. Alignment between NGSS scientific and engineering practices and NAEP TEL practices: Grades 3-5, middle school, and high school

NGSS Scientific and Engineering Practices	NGSS performance expectations		Number aligned with each NAEP TEL practice			
	Number	Percentage	Understanding technological principles	Developing solutions and achieving goals	Communicating and collaborating	No primary alignment
Total	42	100	5	26	3	8
Percent of total, by NAEP TEL practice	†	†	12	62	7	19
1. Asking questions and defining problems	4	10	1	3	0	0
2. Developing and using models	2	5	0	1	0	1
3. Planning and carrying out investigations	2	5	0	1	0	1
4. Analyzing and interpreting data	3	7	0	1	0	2
5. Using mathematics and computational thinking	4	10	0	2	1	1
6. Constructing explanations and designing solutions	17	40	0	15	0	2
7. Engaging in argument from evidence	4	10	0	3	0	1
8. Obtaining, evaluating, and communicating information	6	14	4	0	2	0

† Not applicable.

NOTE: The primary NAEP TEL practice was determined as the practice most frequently identified by panelists, provided that at least three panelists agreed. Detail may not sum to totals because of rounding.

4.3 Combining the Science and TEL Comparisons

The results in this section look across the science and TEL comparisons to explore how completely the full range of content and practices in the NGSS are covered by the NAEP science and TEL frameworks. The combined results are distinguished from the separate science and TEL comparison results presented in sections 4.1 and 4.2 in that they (1) combine data from all four NGSS content domains in the natural sciences and engineering design; (2) report results from both the science and TEL comparisons side-by-side; and (3) for the elementary level, present data on science performance expectations from all grades in the lower elementary grade band (K-2) and upper elementary grade band (3-5).[47] The combined results examine both the content overlap and content alignment of the NGSS with the NAEP science and TEL frameworks. Again, content overlap indicates related content at the corresponding grade, whereas content alignment indicates the degree to which that related content was rated as similar—here, examining the NGSS in comparison to both the science and TEL frameworks.

4.3.1 Content overlap of the NGSS with the NAEP science and TEL frameworks

Figure 1 shows the percentage of NGSS performance expectations in each grade band that were grouped with objectives covering related content in the NAEP science and TEL frameworks at the corresponding grade.[48] The percentages 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; (2) a subset of 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 (3-5, middle school, and high school) that were grouped with content in the NAEP TEL framework, but not the science framework (since they do not specify science content). In other words, it shows—at a broad level—the degree to which the content in the NGSS overlaps with content in the NAEP science and TEL frameworks collectively.

Table 20 presents additional detail. It shows the number of NGSS performance expectations at each grade band that were grouped with NAEP science content statements and TEL assessment targets at the corresponding grade, disaggregated by content area (natural sciences and in engineering design). For science, it also presents the number of (1) performance expectations from the lower and higher grades in the 3-5 grade band that were grouped with NAEP at grade 4, and (2) performance expectations from all grade bands that were grouped with NAEP content statements in a higher or lower grade band.

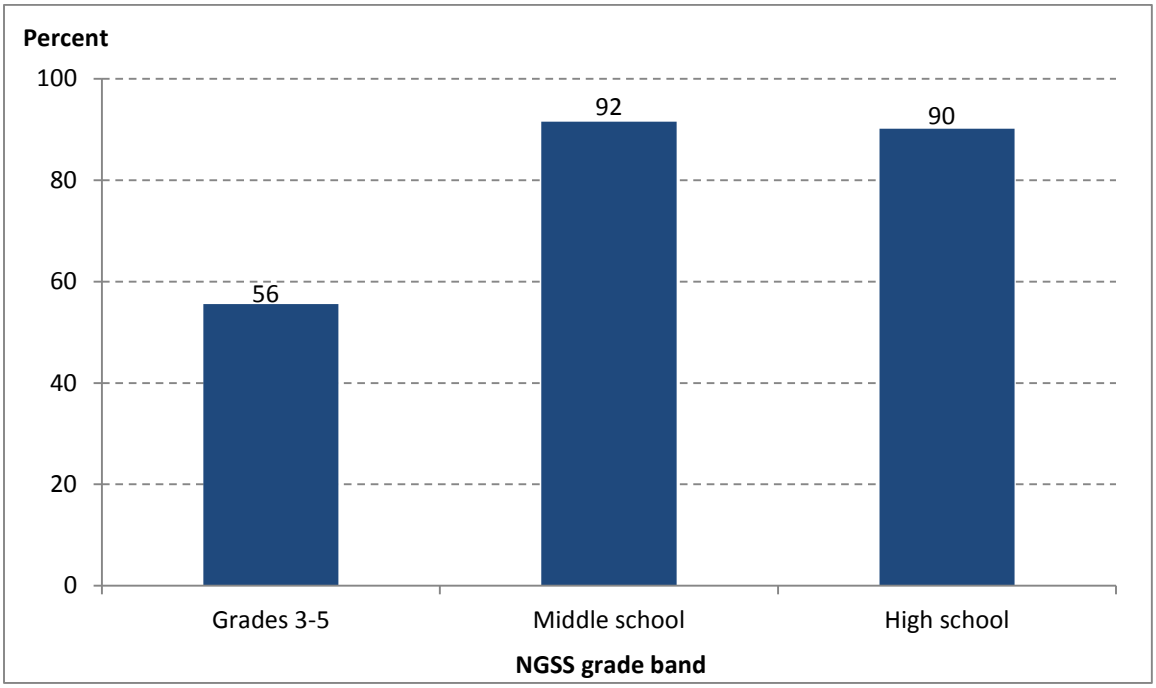
[47] The data on grades K-2, 3, and 5 come from the alternative groupings of NGSS performance expectations with NAEP science content statements at a lower or higher grade level.

[48] NAEP grades 4, 8, and 12 correspond to the NGSS grade bands for grades 3-5, middle school, and high school, respectively. 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.

Figure 1 and table 20 thus provide a more complete picture of the content overlap between the NGSS and NAEP for the entire elementary level and across both the NAEP science and TEL frameworks.

Overall, the NGSS showed moderate to substantial content overlap with the NAEP science and TEL frameworks. Based on the percentage of grouped objectives, 56 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, NAEP TEL, or both 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.

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 (see table 20). 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.[49] 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, four science performance expectations with connections to ETS overlapped content in the TEL framework (three of which were also grouped with NAEP science and one that was grouped only with NAEP TEL).

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.[50] In addition, nearly half (14 of 33) of the performance 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. 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), while 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.

4.3.2 Content alignment between the NGSS and the NAEP science and TEL frameworks

Figure 2 shows the percentage of NGSS performance expectations in each grade band that were rated as similar to objectives in the NAEP science framework only, the NAEP TEL framework only, or

[49] Table 20 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 with content in NAEP grade 4 objectives.

[50] Overall content overlap is the sum of columns 9 to 11 in table 20 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 objectives; and those in engineering design grouped only with NAEP TEL.

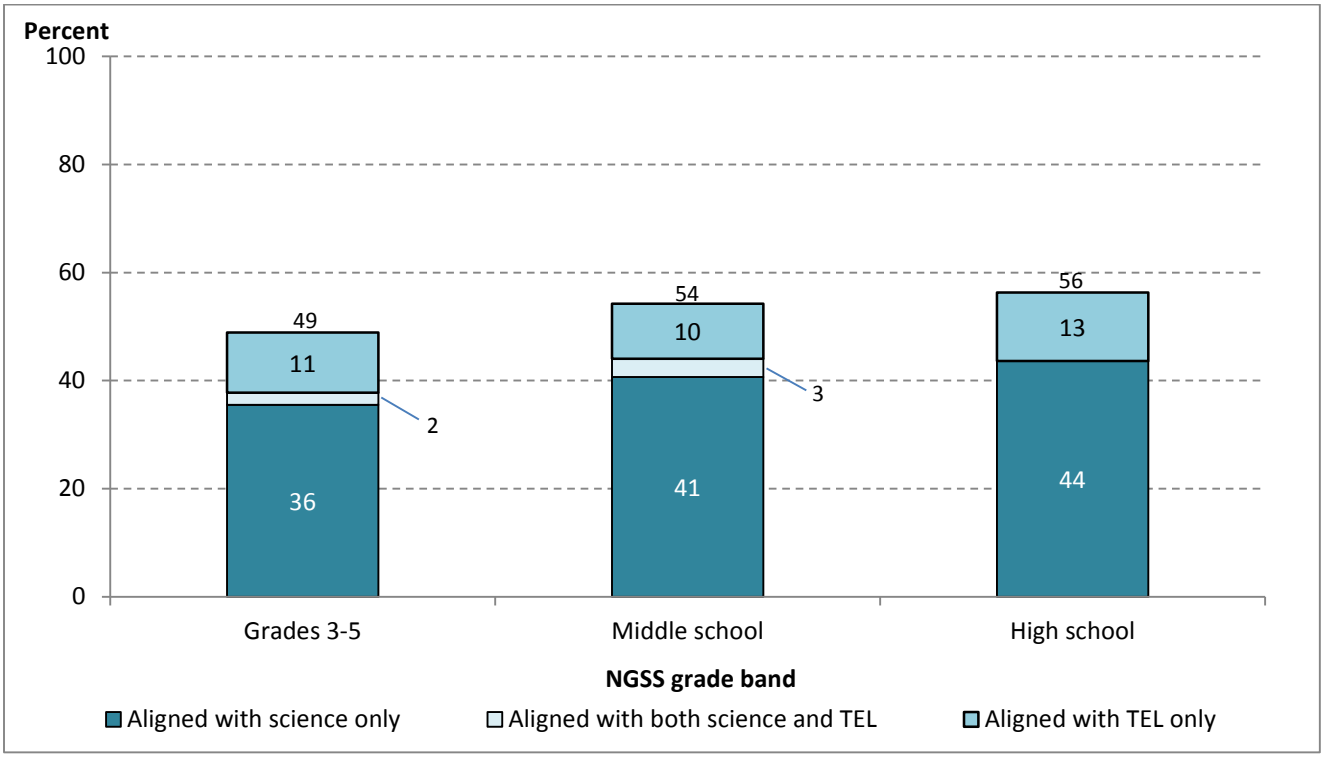
both the science and TEL frameworks, at the corresponding grade. Thus, it shows the degree to which the content in the NGSS aligned with content in the NAEP science and TEL frameworks individually and collectively.

Table 21 presents additional detail. It shows the total number of NGSS performance expectations in each grade band, those that were aligned with the science and TEL frameworks individually, those that were aligned with both frameworks, and the total aligned with either NAEP science or TEL. Together, figure 2 and table 21 provide a more complete picture of the degree of content alignment between the NGSS and NAEP across the elementary grades and across both the NAEP science and TEL frameworks.

Content alignment of the NGSS with the NAEP science and TEL frameworks was moderate at the upper elementary, middle, and high school grade levels. Roughly half of the performance expectations from across all four disciplines in each grade band were aligned to the NAEP science framework, the NAEP TEL framework, or both at the corresponding grades (see figure 2 and table 21). At the upper elementary level (grades 3-5), 22 of 45 NGSS performance expectations across all content domains were aligned to either the NAEP science or TEL framework at grade 4, or both—with the majority (16) aligned only to the science framework (see table 21). Altogether, 17 performance expectations (or 38 percent) aligned to the NAEP science framework and 6 (or 13 percent) aligned to the TEL framework, with 1 performance expectation (2 percent) aligned to both. At the middle school level, 32 of 59 performance expectations were aligned to NAEP at grade 8, with 24 aligned only to the science framework. Altogether, 26 performance expectations (or 44 percent) aligned to the NAEP science framework and 8 (or 10 percent) aligned to the TEL framework, with 2 performance expectations (3 percent) aligned with both. At the high school level, 40 of 71 performance expectations were aligned with NAEP at grade 12, with 31 (44 percent) aligned only to the science framework, and 9 (13 percent) aligned with the TEL framework; no high school performance expectations were aligned with both NAEP science and TEL.

In the natural sciences, a majority of performance expectations were aligned only to the NAEP science framework, but small numbers were aligned only to the TEL framework (2, 3, and 6 at the three grade levels, respectively) or to both frameworks (1 at the upper elementary level and 2 at the middle school level). The performance expectations in science that were aligned with the TEL framework or both the TEL and science frameworks were those with connections to ETS. More specifically, those that were aligned only with the NAEP TEL framework generally required the application of engineering design skills, but involved a science context that was not included in the NAEP science framework at the corresponding grade level. In engineering design, performance expectations were compared only to the TEL framework because they do not specify science content; thus, alignment was only with the TEL framework (all 3 performance expectations at grades 3-5 and 3 of 4 at the middle school and high school levels).

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.

Table 20. 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 grade band (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).

Table 21. 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.

4.4 Mathematics Comparisons

The results from the mathematics comparisons describe the number and percentage of NGSS performance expectations whose associated scientific and engineering practices involve mathematics included in the NAEP mathematics framework at the corresponding grade or in two adjacent grades (i.e., grades 4 and 8 or grades 8 and 12). This is referred to as alignment in mathematics and indicates the extent to which the mathematics that may be involved in items based on the NGSS is included in the NAEP mathematics framework and at what grade level(s).

As described in section 3.3.1, the NGSS performance expectations with scientific and engineering practices that involve mathematics are those identified in the NGSS as having connections to the Common Core State Standards for Mathematics. These reflect the majority of NGSS performance expectations in both the natural sciences and engineering design disciplines and cover all (or nearly all) of the scientific and engineering practices at each grade level: 13 of the 17 NGSS performance expectations at grade 4, 52 of 59 at the middle school level, and 59 of 71 at the high school level.[51]

[51] The total numbers of NGSS performance expectations in the sciences and engineering design are presented in tables 4 and 5, respectively; the number of those that involve mathematics-related practices is presented in table 22.

Results are shown for each NGSS grade band (see table 22). The quantitative results in this section are also supported by qualitative descriptions of the mathematics-related practices measured by the NGSS performance expectations at each grade level and the mathematics content of aligned NAEP objectives (see appendix G).

Most NGSS performance expectations involving mathematics were aligned with objectives in the NAEP mathematics framework at the corresponding grade. All of the NGSS performance expectations involving mathematics at grade 4 were aligned to NAEP—that is, the mathematics deemed to be required in items based on these performance expectations was consistent with one or more mathematics objectives in the NAEP framework at grade 4 (see table 22). Eighty-seven percent of performance expectations at the middle school level and 97 percent at the high school level were aligned to the NAEP framework at grades 8 and 12, respectively.

However, a substantial 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 NGSS performance expectations at grade 4 involved some mathematics that was more consistent with NAEP objectives at grade 8, and 27 percent of those at middle school involved some mathematics that was more consistent with NAEP objectives at grade 12. This means that these performance expectations involve some mathematics covered in NAEP objectives at the corresponding grade and some mathematics covered in NAEP objectives at the higher grade.

- Performance expectations at grade 4 that were aligned with grade 8 mathematics objectives in NAEP included those involving percentages and rates, geometrical models (e.g., waves, light reflection, cross-sections of solids), large time scales, physical attributes (e.g., area, volume, weight/mass), designing investigations (e.g., criteria for a fair test, control of variables), characteristics of data sets (e.g., mean, median, mode, range), and patterns in data.

- Performance expectations at grade 8 that were aligned with grade 12 mathematics objectives in NAEP included those involving non-linear relationships (e.g., quadratic, logarithmic, exponential), rate of change (e.g., changes in population growth), working with multiple variables (e.g., constraints and criteria), and mathematical reasoning with data (e.g., critiquing ways of presenting and using data).

- Alignment at a lower grade level in NAEP only occurred—though not frequently—for the NGSS performance expectations in high school, where 14 percent were aligned with the NAEP framework at both grades 8 and 12. High school performance expectations that also aligned at grade 8 involved the use of ratios; measurements of weight/mass, time, and physical attributes; and the interpretation and use of geometric patterns, which are not a focus in the grade 12 NAEP framework.

The percentages of performance expectations involving mathematics that aligned with NAEP objectives only at the corresponding grade level increased over the grade bands. Only 1 of 13 NGSS performance expectations in the 3-5 grade band (8 percent) was aligned only with NAEP objectives at grade 4. In contrast, 60 percent in middle school were aligned only with NAEP at grade 8, and 83 percent in high school were aligned only with NAEP grade 12.

A small percentage of NGSS performance expectations were not aligned with NAEP mathematics objectives at any grade; these were not as quantitatively focused as the other performance expectations. The seven performance expectations in middle school that were not aligned with any NAEP mathematics objective were from the disciplines of life sciences and Earth and space sciences. They focused on observational evidence rather than quantitative data (e.g., fossil record, cellular makeup of organisms, anatomical features) or involved the use of models that the experts judged would not require mathematics as described in NAEP (e.g., cycling of matter and energy flow in food webs). Two performance expectations at the high school level were not aligned to the NAEP mathematics framework because they did not involve measurement—one in life sciences that involved a model of cellular division and differentiation, and one in physical sciences that involved evidence of electromagnetic induction (magnetic field produced by an electric current and electric current produced by a changing magnetic field).

Table 22. 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.

5. Summary and Conclusions

This study provides information primarily on the extent of alignment between the NGSS and NAEP frameworks in science and TEL and identifies areas of similarity and difference between them. In particular, it describes the extent of *content overlap*, reflecting related content and the potential for content alignment, as well as the actual *content alignment*, based on the degree of content similarity.[52] In doing so, it identifies content aligned at the corresponding grade in the NGSS and NAEP frameworks, content aligned at a different grade, and unique content not aligned at any grade in the other framework. It also describes *practices alignment* (that is, the alignment of NGSS performance expectations with a primary NAEP science or TEL practice),[53] and examines the *overall alignment* of the NGSS and NAEP science framework in particular, considering both content and practices. In addition, the study provides information about the level of *mathematics alignment*—the extent to which performance expectations in the NGSS that involve mathematics are covered in the NAEP mathematics framework and at which grades—which supplements the science and TEL comparisons.

The study showed that, despite their differences in goals, there were many similarities between the NGSS and the NAEP science and TEL frameworks. The key results from the science and TEL comparisons are summarized below, focusing mainly on the comparisons of the NGSS with NAEP, although notable findings of the comparisons of NAEP to the NGSS are highlighted as well. These are followed by the key findings from the mathematics comparisons. The conclusions at the end of this section discuss some implications for how NGSS-based assessments might compare with NAEP assessments based on the results of the framework comparison study.

Summary of findings from the science and TEL comparisons

There was a moderate to substantial degree of ***content overlap*** between the NGSS and the NAEP science and TEL frameworks.

- 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. In contrast, there was much less content in NAEP science that overlapped with the NGSS at grade 4 (and in TEL that overlapped at any grade).

- Ninety 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. A somewhat lower, but still substantial, percentage of content in NAEP science at grades 8 and 12 (from 74 to 88 percent) overlapped with the NGSS.

[52] See Exhibit 9 for a summary of key terms.
[53] Related to science and engineering, practices refer to the processes and habits of mind that students develop and apply to demonstrate their knowledge and cognition in these disciplines.

Because of differences in the depth, breadth, detail, or focus of the overlapping content, *content alignment* was lower than *content overlap* when the NGSS was compared to the NAEP science and TEL frameworks together. Moreover, when relevant performance expectations in the natural sciences (physical sciences, life sciences, and Earth and space sciences) and in engineering, technology, and applications of science (ETS) were compared to the NAEP science and TEL frameworks individually, content alignment differed by grade and by content domain.

- Across frameworks, content alignment of the NGSS with the NAEP science and TEL frameworks was moderate. Roughly half of the NGSS performance expectations aligned to NAEP (science or TEL) at each grade level. At grades 3-5, 38 percent of performance expectations were aligned with the science framework and 13 percent with the TEL framework, with 2 percent in the sciences aligned with both NAEP and TEL. At the middle school level, 44 percent of performance expectations were aligned with the science framework and 13 percent with the TEL framework, with 3 percent in the sciences aligned with both. At the high school level, 44 percent of performance expectations were aligned with the science framework and 13 percent with the TEL framework (with no performance expectations aligned with both).

- When looking only at the performance expectations in science, the content alignment of the NGSS with the NAEP science framework was low at grade 4 (36 percent) and moderate at the middle school and high school levels (about 50 percent at each grade level). Comparing NAEP science to the NGSS, alignment at grades 4 and 8 was similarly low (23 percent) and moderate (56 percent), respectively; at grade 12, the alignment of NAEP to the NGSS was substantial (71 percent).

- Across grades, the greatest degree of alignment between the NGSS and the NAEP science framework was in life sciences and the lowest was in physical sciences, based on the content similarity ratings at both the objective level and at the content area level as a whole. From 48 to 54 percent of NGSS performance expectations in life sciences were aligned with NAEP objectives compared to from 29 to 42 percent of NGSS performance expectations in physical sciences. Looking at the content areas as a whole, life sciences was the only content area rated as similar at two grades (grades 8 and 12) whereas physical sciences was rated as similar only at grade 12, and Earth and space sciences only at grade 8. None of the content areas as a whole were rated as similar at grade 4.

- When looking only at the performance expectations in engineering, technology, and applications of science (ETS), content alignment to the NAEP TEL framework was strong for NGSS performance expectations in engineering design (at least 75 percent at each grade level), but weaker for those in the sciences with connections to ETS, especially at the upper grades (as low as 38 percent). The alignment of NAEP TEL with the NGSS, in contrast, was weak at all grade levels, because there are many more assessment targets in NAEP TEL as well as assessment areas or subareas that do not have corresponding disciplinary core or

component ideas in the NGSS. In addition to engineering design at all three grade levels, both the NGSS and NAEP TEL include the effects of technology on society and the natural world at the middle and high school levels.

The NGSS and NAEP science framework emphasize some content at different grades. That is, 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—representing no more than one-fifth of the objectives. The one exception was for NAEP science at grade 4, where 59 percent of content statements were aligned at a lower or higher grade in the NGSS. The percentage aligned at a different grade decreased over the grade levels for both the NGSS and the NAEP science framework.

- Notably, the NGSS and NAEP objectives at middle school/grade 8 that were aligned to other grades were only aligned at the higher grade level in the other framework (high school/grade 12)—i.e., none of the middle school performance expectations were aligned with NAEP grade 4 content statements in science, and none of the NAEP grade 8 content statements in science were aligned with NGSS performance expectations in grades K-5. In addition, some objectives at high school/grade 12 in both the NGSS and NAEP were aligned at the middle school/grade 8 level in the other framework. Thus, the difference between the NGSS and NAEP science framework at grade 8 was more in terms of what content is emphasized in middle school versus high school.

Both the NGSS and the NAEP science and TEL frameworks include objectives at each grade level that cover *unique content*. This reflects non-grouped objectives covering content that is in one framework but not in its counterpart at any grade. (Examples are given in exhibits 10-12 for science and exhibit 13 for TEL). The unique content, together with content that overlapped but was not aligned at any grade in the counterpart framework, represented between 43 and 48 percent of NGSS performance expectations in science and between 18 and 28 percent of NAEP science content statements. Unique content also represented between 14 and 55 percent of NGSS performance expectations in ETS and between 72 and 87 percent of NAEP TEL assessment targets. Unique content reflects areas where each program can contribute different information about student outcomes.

Practices alignment was uniformly strong, but the emphasis of NGSS performance expectations across the NAEP science and TEL practices differed from the emphases specified in the NAEP frameworks.

- Ninety-nine percent of NGSS performance expectations in science were aligned to NAEP science practices and 81 percent of performance expectations in ETS were aligned to NAEP TEL practices.

- The NGSS performance expectations in science were more strongly concentrated in the NAEP science practice of *using science principles* (60 percent across grades) than was specified in the NAEP science framework (30 to 40 percent across grades). In contrast, very few of the NGSS performance expectations aligned with *identifying science principles* (4 percent across grades) compared to the 20 to 30 percent specified for NAEP across grades. The emphasis on *using scientific inquiry* (22 percent) and *using technological design* (13 percent) was more comparable to NAEP science (30 and 10 percent, respectively, across grades).

- The NGSS performance expectations in ETS were strongly concentrated in the NAEP TEL practice of *developing solutions and achieving goals* (62 percent across grades), which was greater than what is specified in the NAEP TEL frameworks (40 percent across grades). Only small percentages of NGSS performance expectations aligned with NAEP's *understanding technological principles* (12 percent) and *communicating and collaborating* (7 percent) (compared to 30 percent in each practice across grades in NAEP TEL).

However, despite some strong indications of alignment between the NGSS and NAEP content and practices dimensions separately, when both content and practices were considered together, the NGSS and NAEP science framework were found to be not aligned at the *overall framework level*. That is, at each grade level, the two frameworks were rated as not similar. This was generally because panelists thought that the individual NGSS performance expectations often went beyond what would be expected based on the descriptions of the practices in the NAEP framework when they are applied to specific content statements, even if the science content covered was similar to that in the NGSS.

Summary of findings from the mathematics comparisons

While most of the NGSS performance expectations involving mathematics were aligned with objectives in the NAEP mathematics framework at the corresponding grade, a significant percentage also aligned to the next higher grade.

- All of the mathematics-related performance expectations at grade 4 and at least 87 percent at the middle and high school levels were aligned with NAEP objectives.

- However, 92 percent of the performance expectations at grade 4 involved some mathematics that was more consistent with NAEP objectives at grade 8 and were aligned at both 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.

Conclusions

Together, the results from the various components of the comparison study suggest that NGSS-based assessments and NAEP science and TEL assessments would be aligned to some degree, but each would also have unique content and different emphases in terms of science and TEL practices. This is because some of the grouped NGSS and NAEP objectives with overlapping content—those that were aligned —would likely lead to similar assessment items, but some were different enough that they would likely lead to assessment items with a different content focus. Additionally, those objectives that were not grouped (and either aligned at a lower or higher grade or not aligned at all) would represent unique content at the given grade.

For example, content alignment of an NGSS-based assessment with the NAEP science assessment would likely be low at grade 4—moderate if the entire upper elementary grade band was considered—and moderate at the middle and high school levels. The specific topics that would likely be aligned in science assessments are those identified in exhibits 10-12, along with the topics that would likely be aligned at other grade levels or unique to each program. The lower alignment at grade 4 relates to the greater breadth of content in NAEP (evidenced by the greater number of non-grouped objectives) and the fact that some of the content in NAEP at grade 4 may be covered at a different grade in the NGSS's upper elementary grade band.

An NGSS-based assessment also would likely have a much greater emphasis—over half the assessment—on *using science principles* and a much lesser emphasis on *identifying science principles* than a NAEP science assessment—only 4 percent.[54] This is not surprising given that NAEP explicitly includes declarative knowledge in this latter practice, where the NGSS emphasize the application of science knowledge.

Another implication looking across the study is that the content and practices embodied in NGSS performance expectations that involve engineering design are not fully covered by either the NAEP science or NAEP TEL framework, despite strong alignment with the engineering design assessment targets in NAEP TEL. (This includes both performance expectations in engineering design and those in the sciences that involve design applications.) Thus, assessment tasks involving engineering design could look quite different in the two programs despite these areas of overlap.

The NAEP science framework—which specifies the practice of *using technological design* (with which many of the NGSS performance expectations in science that involve design applications aligned)—is restricted to the consideration of scientific criteria, constraints, and trade-offs in making design decisions. This is in contrast to the NGSS (and NAEP TEL), which more fully reflect the engineering design process and include a broader range of considerations such as social and economic factors (excluded in NAEP science). Additionally, the NAEP TEL framework and assessments do not

[54] Of course, the distribution across practices in an NGSS-based assessment would depend on how the assessment is actually constructed, which is not specified.

expect prior science content knowledge, in contrast to the NGSS, which require the application of science concepts. NAEP TEL, rather, provides the background on the science concepts needed to be successful on the items and tasks measuring the engineering design process.

A final implication is that the tasks that could be developed to assess the NGSS performance expectations in science and engineering would likely require students to use some mathematics that is beyond the corresponding grade level in the NAEP mathematics framework; in contrast, the NAEP science and TEL assessments require mathematics at or below the corresponding grade. In other words, some of the mathematics that could be required in an NGSS-based assessment would be at a higher level than what is required in NAEP science and TEL assessments.

In conclusion, 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 to NAEP assessments, future studies that compare the content of actual assessments based on these frameworks—and including the full upper elementary grade band of the NGSS—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.

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

List of Science and TEL Expert Panelists

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Kathleen Scalise
Educational Testing Service
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Jacqueline Smalls
Science Education Manager
Center for Inspired Teaching
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Jacqueline Smalls
Science Education Manager
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[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.

List of Research Team Members

The research team from American Institutes for Research (AIR) 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

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Principal Psychometrician/ Statistician

Kim Gattis
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Maria Stephens
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Yan Wang
Senior Psychometrician/ Statistician

Jiao Yu
Research Associate

Appendix B: Comparison of the NGSS and NAEP Framework Dimensions

Exhibit B-1. Comparison of the NGSS and NAEP science framework content dimensions

NGSS Disciplinary Core and Component Ideas	NAEP Science Framework Topics and Subtopics
Physical Sciences	
PS1. Matter and its interactions A. Structure and properties of matter B. Chemical reactions C. Nuclear processes PS2. Motion and stability: Forces and interactions A. Forces and motion B. Types of interactions C. Stability and instability in physical systems PS3. Energy A. Definitions of energy B. Conservation of energy and energy transfer C. Relationship between energy and forces D. Energy in chemical processes and everyday life PS4. Waves and their applications in technologies for information transfer A. Wave properties B. Electromagnetic radiation C. Information technologies and instrumentation	1. Matter a) Properties of matter b) Changes in matter 2. Energy a) Forms of energy b) Energy transfer and conservation 3. Motion a) Motion at the macroscopic level b) Forces affecting motion

NGSS Disciplinary Core and Component Ideas	NAEP Science Framework Topics and Subtopics
Life Sciences	
LS1. From molecules to organisms: Structures and processes A. Structure and function B. Growth and development of organisms C. Organization for matter and energy flow in organisms D. Information processing LS2. Ecosystems: Interactions, energy, and dynamics A. Interdependent Relationships in Ecosystems B. Cycles of matter and energy transfer in ecosystems C. Ecosystem dynamics, functioning, and resilience D. Social interactions and group behavior LS3. Heredity: Inheritance and variation of traits A. Inheritance of traits B. Variation of traits LS4. Biological evolution: Unity and diversity A. Evidence of common ancestry and diversity B. Natural selection C. Adaptation D. Biodiversity and humans	1. Structures and Functions of Living Systems a) Organization and development b) Matter and energy transformations c) Interdependence 2. Changes in Living Systems a) Heredity and reproduction b) Evolution and diversity

NGSS Disciplinary Core and Component Ideas	NAEP Science Framework Topics and Subtopics
Earth and Space Sciences	
ESS1. Earth's place in the universe A. The universe and its stars B. Earth and the solar system C. The history of planet Earth ESS2. Earth's systems A. Earth materials and systems B. Plate tectonics and large-scale system interactions C. The roles of water in Earth's surface processes D. Weather and climate E. Biogeology ESS3. Earth and human activity A. Natural resources B. Natural hazards C. Human impacts on Earth systems D. Global climate change	1. Earth in space and time a) Objects in the universe b) History of Earth 2. Earth structures a) Properties of Earth materials b) Tectonics 3. Earth systems a) Energy in Earth systems b) Climate and weather c) Biogeochemical cycles

NOTE: This table compares the disciplinary core and component ideas in the NGSS in the science disciplines with the content areas, topics and subtopics in the NAEP science framework.

SOURCE: National Assessment Governing Board (NAGB), *Science Framework for the 2015 National Assessment of Educational Progress*, 2014. National Research Council (NRC), *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* 2012.

Exhibit B-2. Comparison of the NGSS and NAEP science framework practices dimensions

NGSS Scientific and Engineering Practices	NAEP Science Framework Science 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	1. Identifying science principles • Describe, measure, or classify observations • State or recognize correct science principles • Demonstrate relationships among closely related science principles • Demonstrate relationships among different representations of principles and data patterns 2. Using science principles • Explain observations of phenomena • Predict observations of phenomena • Suggest examples of observations that illustrate a science principle • Propose, analyze, and/or evaluate alternative explanations or predictions 3. Using scientific inquiry • Design or critique aspects of scientific investigations • Conduct scientific investigations using appropriate tools and techniques • Identify patterns in data and/or relate patterns in data to theoretical model • Use empirical evidence to validate or criticize conclusions about explanations and predictions 4. Using Technological Design • Propose or critique solutions to problems given criteria and scientific constraints • Identify scientific tradeoffs in design decisions and choose among alternative solutions • Apply science principles or data to anticipate effects of technological design decisions

NOTE: This exhibit compares the eight scientific and engineering practices in the NGSS with the four science practices in the NAEP science framework. In the NAEP Science Framework, the bullets indicate the general performance expectations associated with each practice.

SOURCE: National Assessment Governing Board (NAGB), *Science Framework for the 2015 National Assessment of Educational Progress*, 2014. National Research Council (NRC), *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* 2012.

Exhibit B-3. Comparison of the NGSS and NAEP technology and engineering literacy (TEL) framework content dimensions

NGSS **Disciplinary Core and Component Ideas** **Engineering, Technology, and Applications of Science (ETS)**	**NAEP TEL Framework** **Assessment Areas and Subareas**
ETS1: Engineering Design A. Defining and delimiting an engineering problem B. Developing possible solutions C. Optimizing the design solution ETS2: Links Among Engineering, Technology, Science, and Society A. Interdependence of science, engineering, and technology B. Influence of engineering, technology, and science on society and the natural world	1. Design and Systems • Nature of technology • Engineering design • Systems thinking • Maintenance and troubleshooting 2. Technology and Society • Interaction of technology and humans • Effects of technology on the natural world • Effects of technology on the world of information and knowledge • Ethics, equity, and responsibility 3. Information and Communication Technology • Construction and exchange of ideas and solutions • Information research • Investigation of problems • Acknowledgment of ideas and information • Selection and use of digital tools

NOTE: This table compares the disciplinary core and component ideas in the NGSS in "engineering, technology, and applications of science" (ETS) with the assessment areas and subareas in the NAEP TEL framework. The NGSS include a set of grade-specific performance expectations for each of the component ideas in "engineering design" (ETS1). The core and component ideas of "links among engineering, technology, science, and society" (ETS2) are measured by some of the performance expectations in the science disciplines that have explicit crosscutting connections to ETS.

SOURCE: National Assessment Governing *Board* (NAGB), *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress,* 2013. National Research Council (NRC), *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* 2012.

Exhibit B-4. Comparison of the NGSS and NAEP technology and engineering literacy (TEL) framework practices dimensions

NGSS Scientific and Engineering Practices	NAEP TEL Framework 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	1. Understanding technological principles • Demonstrate knowledge and understanding of technology • Reason about facts, concepts, and principles and their interrelationships • Explain features and functions of technologies and systems • Make predictions, comparisons, and evaluations • Identify examples; explain, describe, analyze, compare, relate, and represent technological principles • Understand relationships among components of systems 2. Developing solutions and achieving goals • Systematically apply technological knowledge, tools, and skills to address problems and achieve goals • Demonstrate procedural and strategic capabilities and the ability to apply tools and design strategies to address authentic tasks • Analyze goals • Plan, design, and implement problem-solving strategies • Monitor, iteratively revise, and evaluate possible solutions 3. Communicating and collaborating • Use contemporary technologies to communicate for a variety of purposes • Develop representations • Share ideas, designs, data, explanations, models, arguments, and presentations • Engage with virtual (computer-generated) peers and experts to achieve goals

NOTE: This exhibit compares the eight scientific and engineering practices in the NGSS with the three technology and engineering practices in the NAEP TEL framework. In the NAEP TEL Framework, the bullets indicate expectations associated with each practice.

SOURCE: National Assessment Governing *Board* (NAGB), *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress,* 2013. National Research Council (NRC), *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* 2012.

Exhibit B-5. Comparison of the NGSS scientific and engineering practices and NAEP mathematics framework content areas and subtopics

NGSS **Scientific and Engineering Practices**	**NAEP Mathematics Framework** **Content Areas and Subtopics**
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	Number Properties and Operations 1) Number sense 2) Estimation 3) Number operations 4) Ratios and proportional reasoning 5) Properties of number and operations 6) Mathematical reasoning using number Measurement[1] 1) Measuring physical attributes 2) Systems of measurement 3) Measurement in triangles Geometry[1] 1) Dimension and shape 2) Transformation of shapes and preservation of properties 3) Relationships between geometric figures 4) Position, direction, and coordinate geometry 5) Mathematical reasoning in geometry Data Analysis, Statistics and Probability 1) Data representation 2) Characteristics of data sets 3) Experiments and samples 4) Probability 5) Mathematical reasoning with data Algebra 1) Patterns, relations, and functions 2) Algebraic representations 3) Variables, expressions, and operations 4) Equations and inequalities 5) Mathematical reasoning in algebra

[1]At grade 12, Geometry and Measurement are combined into one content area.

NOTE: This exhibit compares the eight scientific and engineering practices in the NGSS with the five (four in grade 12) content areas in the NAEP Mathematics Framework. In the NAEP Mathematics Framework, the numbered lists indicate the subtopics associated with each content area.

SOURCE: National Assessment Governing Board (NAGB), *Mathematics Framework for the 2015 National Assessment of Educational Progress*, 2014. National Research Council (NRC), *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* 2012.

Appendix C: Methodology Exhibits

Exhibit C-1. Examples of the different types of grouped and non-grouped objectives

Type	Description	NGSS Performance Expectation (PE)	NAEP Content Statement(s) (CS)
Grouped 1 PE / 1 CS	A single NGSS PE grouped with a single NAEP CS	MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.	P8.16. Forces have magnitude and direction. Forces can be added. The net force on an object is the sum of all the forces acting on the object. A nonzero net force on an object changes the object's motion; that is, the object's speed and/or direction of motion changes. A net force of zero on an object does not change the object's motion; that is, the object remains at rest or continues to move at a constant speed in a straight line.
Grouped 1 PE / 2 CS	A single NGSS PE grouped with multiple NAEP CS's	HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.	P12.03. In the periodic table, elements are arranged according to the number of protons (called the atomic number). This organization illustrates commonality and patterns of physical and chemical properties among the elements. --- P12.06. An atom's electron configuration, particularly of the outermost electrons, determines how the atom can interact with other atoms. The interactions between atoms that hold them together in molecules or between oppositely charged ions are called chemical bonds.
Grouped 2 PE / 1 CS	A single NAEP CS grouped with multiple NGSS PE's	4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.	P4.11. Electricity flowing through an electrical circuit produces magnetic effects in the wires. In an electrical circuit containing a battery, a bulb, and a bell, energy from the battery is transferred to the bulb and the bell, which in turn transfer the energy to their surroundings as light, sound, and heat (thermal energy).
		4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.	P4.11. Electricity flowing through an electrical circuit produces magnetic effects in the wires. In an electrical circuit containing a battery, a bulb, and a bell, energy from the battery is transferred to the bulb and the bell, which in turn transfer the energy to their surroundings as light, sound, and heat (thermal energy).
Non-grouped PE	NGSS PE not grouped with any NAEP CS's	HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.	None
Non-grouped CS	NAEP CS not grouped with any NGSS PEs	None	P8.02. Chemical properties of substances are explained by the arrangement of atoms and molecules.

Exhibit C-2. Example of a split NAEP content statement and resulting similarity ratings

Grouped Objectives		Aggregate Group Rating (by panel)	NGSS PE Rating	NAEP Partial Content Statement Rating	Overall NAEP Content Statement Rating
NGSS Performance Expectation (PE)	NAEP Content Statement(s)				
MS-PS1-1: Develop models to describe the atomic composition of simple molecules and extended structures.	P8.04A: **Elements are a class of substances composed of a single kind of atom. Compounds are composed of two or more different elements.** Each element and compound has physical and chemical properties, such as boiling point, density, color, and conductivity, which are independent of the amount of the sample.	Not Similar	0	0	0.5
MS-PS1-2: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	P8.04B: Elements are a class of substances composed of a single kind of atom. Compounds are composed of two or more different elements. **Each element and compound has physical and chemical properties, such as boiling point, density, color, and conductivity, which are independent of the amount of the sample.**	Similar	1	1	
	P8.07: Chemical changes can occur when two substances, elements, or compounds react and produce one or more different substances whose physical and chemical properties are different from the reacting substances.			N/A	1

NOTE: Ratings are provided and aggregated at the group level: NGSS performance expectations grouped with NAEP content statement(s). The analysis calculates similarity ratings at the specific objective level: once based on the NGSS PE and once based on the NAEP content statement(s). Thus for NAEP, where content statements may be split across groupings, weighting is required, as demonstrated for P8.04 in this table. The first part of P8.04A (bolded in the first row) is grouped with MS-PS1-1; the second part of P8.04B (bolded in the second row) is grouped with MS-PS1-2 (along with another content statement P8.07). The light gray portion indicates that part of P8.04 that is not considered in the rating for each group. P8.04 was rated as not similar for the first part and similar for the second part, with an overall similarity rating of 0.5.

Exhibit C-3. Example science data collection form

Physical Science: Grade 12

Panelist 01

Seq. #	NGSS P.E.	NAEP C.S	Content Rating (0,1,2,3,4)		NAEP Practices Alignment (1= Primary; 2= Secondary)								Other Grouping		Alignment to K12 Framework	Comments
					Initial				Final							
			_01	_01	_01	_01	_01	_01	_01	_01	_01	_01	_01	_01	_01	
			Initial	Final	ISP	USP	USI	UTD	ISP	USP	USI	UTD	NGSS P.E.	NAEP C.S.	K12 FW DCI or CCC	
1	HS-PS1-1	P12.03 P12.04														
2	HS-PS1-2	P12.07 P12.06 P12.03														
3	HS-PS1-3	P12.12														

Exhibit C-4. Example TEL data collection form

Engineering, Technology and Applications of Science: Grade 12

Panelist 04

Seq. #	NGSS P.E.	NAEP TEL Tar.	NAEP Science C.S.	Content Rating (0,1,2,3,4)		NAEP Practices Alignment (1= Primary; 2= Secondary)						Other Grouping		Alignment to K12 Framework	Comments
						Initial			Final						
				_04	_04	_04	_04	_04	_04	_04	_04	_04	_04	_04	
				Initial	Final	UTP	DSAG	CC	UTP	DSAG	CC	NGSS P.E.	NAEP C.S.	K12 FW DCI or CCC	
1	HS-ETS1-1	D.12.08 T.12.03 T.12.07													
2	HS-ETS1-2	D.12.06 D.12.08 D.12.09													
3	HS-ETS1-3	D.12.06 D.12.07 D.12.08													

Exhibit C-5. Crosswalk of associated science and TEL tables, figures, and exhibits, by types of analyses and data sources

Types of Analyses		Associated Tables, Figures, and Exhibits		Ratings/Data Source
		Science	TEL	
Content overlap	Content groupings by grade level	Tables 6 and 7	Tables 14 and 15	Final content groupings and objective-level content similarity ratings
Content alignment and grade-level alignment	Content alignment	Tables 8-A-C	Tables 16 and 17	Objective-level content similarity ratings
	Grade-level alignment	Tables 8-A-C	n/a	Grade-level alignment
	Content alignment by NGSS crosscutting concepts	Tables 9-A-D	n/a	Objective-level content similarity ratings
	Content alignment at the content area level	Table 10	n/a	Content area content similarity ratings
	Content alignment between NGSS and NAEP at the overall framework level	Table 13	n/a	Overall framework similarity ratings
Practices alignment	Alignment of NGSS performance expectations with NAEP practices	Table 11	Table 18	Objective-level practices alignment
	Alignment between NGSS practices and NAEP practices	Table 12-A-D	Table 19-A-D	Objective-level practices alignment
Summary and other	Combining the science and TEL results	Tables 20 and 21 Figures 1 and 2		Final content groupings, content alignment, and grade-level alignment
	Content comparison exhibits[1]	Appendix E	Appendix F	Objective-level content similarity ratings, practices alignment, panel discussion, and comments
	Content comparison summary exhibits[1]	Exhibits 10, 11, and 12	Exhibit 13	Objective-level content similarity ratings, panel discussion, and comments

[1] These exhibits are based primarily on qualitative analyses, whereas the other tables, figures, and exhibits are based on quantitative analyses.

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

Appendix D 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 D-1: NGSS performance expectations in the 3–5 grade band compared with the NAEP assessment frameworks at grade 4
- Exhibit D-2: NGSS performance expectations in the middle school grade band compared with the NAEP assessment frameworks at grade 8
- Exhibit D-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 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, or 3). For example, the first DCI in life sciences (LS1) includes two PEs at grade 4 (4-LS1-1 and 4-LS1-2),

[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.

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

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.

[3] The "not similar" category in appendix D reflects the expert panel ratings only for grouped PEs. In contrast, the reporting category of "not similar" in tables 8 and 16 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 D-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 D-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 D-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 D-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 D-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.

Appendix E: Content Comparison of NGSS Performance Expectations and NAEP Science Content Statements

Appendix E includes detailed content comparisons of NGSS performance expectations in the science disciplines and NAEP science content statements. There are six exhibits, one for each grade level within each science content area:

Exhibit E-1a: Physical Sciences – Grade 4

Exhibit E-1b: Physical Sciences – Middle School/Grade 8

Exhibit E-1c: Physical Sciences – High School/Grade 12

Exhibit E-2a: Life Sciences – Grade 4

Exhibit E-2b: Life Sciences – Middle School/Grade 8

Exhibit E-2c: Life Sciences – High School/Grade 12

Exhibit E-3a: Earth and Space Sciences – Grade 4

Exhibit E-3b: Earth and Space Sciences – Middle School/Grade 8

Exhibit E-3c: Earth and Space Sciences – High School/Grade 12

These exhibits present the NGSS performance expectations (and disciplinary core ideas from the NRC K-12 framework on which they are based) and list the NAEP science content statements with which they were compared. They provide similarity ratings for each content grouping and summary statements with descriptive information about the areas of similarity and dissimilarity between the NGSS and NAEP science at the corresponding grade level, as well as some cross-grade differences. These summary statements are based on discussions during the expert panel meeting; information provided in the NGSS (descriptions of performance expectations, clarification statements, assessment boundaries, and elements of the underlying disciplinary core ideas from the NRC K-12 framework); and information in the NAEP science framework and assessment and item specifications (content statements, subtopic-level content boundaries, and content statement elaborations).

There are three main sections in each exhibit:

(1) **NGSS performance expectations grouped with NAEP science content statement(s) at the corresponding grade**: This is the first section at the top of each exhibit. It presents the NGSS performance expectations that were grouped with NAEP content statements at the corresponding grade level. Each grouping was rated for similarity of content and practices alignment. Groupings of NGSS performance expectations and NAEP content statements indicate overlapping content that was directly compared. "Similar" indicates that two-thirds or more of panelists rated a specific content grouping as similar ("quite similar but with some differences" or "exactly or almost the same"); otherwise, it is "Not Similar." The summary statement column lists the NAEP content statement(s) that were grouped with each NGSS performance expectation and the primary NAEP science practice with which it was aligned.[1] In addition, NGSS performance expectations and NAEP content statements that were included in the cross-grade alignment results are identified.[2] (See the NAEP science framework (NAGB 2014b) for the full description of content statements and practices.)

(2) **NGSS performance expectations not included in the NAEP science framework at the corresponding grade**: This is the second section in each exhibit. It presents the NGSS performance expectations that were not grouped with any NAEP content statements. "NGSS Only" means that all panelists agreed that there was no corresponding content statement in the NAEP science framework at the same grade level. This section reflects "unique" content in the NGSS for the particular grade and content area. Although these NGSS performance expectations were not grouped with any NAEP content statement(s), they were still judged for alignment with NAEP practices. The primary practice is identified in the summary statement column. NGSS performance expectations that were included in the cross-grade alignment results are also indicated.

(3) **NAEP science content statements not included in the NGSS at the corresponding grade**: This is the last section in each exhibit. It presents the NAEP science content statements (organized by the NAEP subtopics) that were not grouped with any NGSS performance expectation. "NAEP Only" means that all panelists agreed that there was no corresponding NGSS performance expectation at the same grade level with which it should be grouped. This section reflects "unique" content in NAEP for the particular grade and content area. NAEP content statements that were included in the cross-grade alignment results are also indicated.

[1] There is one high school (grade 12) NGSS performance expectation that was judged as not aligned with a primary NAEP science practice. This performance expectation is indicated as "No Primary NAEP Science Practice."

[2] Objectives identified as aligned at a higher or lower grade level were those that were rated as "not similar" at the corresponding grade (grouped and not similar or not grouped) and where the panel identified similar objectives at a different grade. For NAEP content statements grouped with more than one NGSS performance expectation, cross-grade assignment is included only if the content statement is rated as "not similar" to all grouped NGSS performance expectations.

Exhibit E-1a. Content comparison of NGSS performance expectations and NAEP science content statements: Physical sciences, grade 4

NGSS Performance Expectations Grouped with NAEP Science Content Statement(s) at Grade 4			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Definitions of Energy Conservation of Energy and Energy Transfer	4-PS3-2: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.	Similar	Both the NGSS and NAEP include knowledge of heat, sound, light, and electricity as forms of energy. The focus of the NGSS is on energy transfer and how various phenomena provide evidence of energy moving from place to place. NAEP includes knowledge of these forms of energy and specific energy transfers in an electrical circuit (battery, bulb, and bell) at grade 4. A broader application of the concept of energy transfer is not included until grade 8 in NAEP. *NAEP Content Statement(s):* P04.07, P04.11 *NAEP Science Practice*: Using Science Principles
Conservation of Energy and Energy Transfer Energy in Chemical Processes and Everyday Life	4-PS3-4: Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.	Similar	Both the NGSS and NAEP include knowledge of devices that convert energy from one form to another. The NGSS include more examples of devices, such as solar heaters (heat energy) and cars (energy of motion), while NAEP only specifies energy transfers in electrical circuits (battery, bulb, and bell). *NAEP Content Statement(s):* P04.11 *NAEP Science Practice*: Using Technological Design
Wave Properties	4-PS4-1: Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.	Not Similar	The topic of waves is covered at different levels in the NGSS and NAEP. The NGSS include using models to describe patterns in amplitude and wavelength of various waves and that those waves can cause objects to move. NAEP includes basic knowledge of sound – produced by vibrating objects; pitch is related to the speed of vibration; and sound can be transmitted through air, liquids, and solids. However, NAEP does not include broader knowledge of wave patterns at grade 4. NAEP includes waves at grade 8, but focuses on waves as a form of energy and as a means of transferring energy. The concept of sound produced by vibrating objects in NAEP at grade 4 is included at grade 1 in the NGSS (1-PS4-1). *NAEP Content Statement(s)*: P04.10 *NAEP Science Practice*: Using Science Principles *Cross-grade alignment*: P04.10 at a lower grade in the NGSS

Electromagnetic Radiation	4-PS4-2: Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.	Not Similar	The topic of light is covered at different levels in the NGSS and NAEP. At grade 4, the NGSS focus on how reflected light allows objects to be seen. NAEP includes basic properties of light (travels in straight lines, reflection, absorption, shadow formation, bending in water or air) but does not explicitly include how light allows objects to be seen. Some of the basic concepts related to the behavior of light included at grade 4 in NAEP are included in grade 1 in NGSS (1-PS4-3). *NAEP Content Statement(s)*: P04.09 *NAEP Science Practice*: Using Science Principles *Cross-grade alignment*: P04.09 at a lower grade in the NGSS
NGSS Performance Expectations Not Included in NAEP Science at Grade 4			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Definitions of Energy	4-PS3-1: Use evidence to construct an explanation relating the speed of an object to the energy of that object.	NGSS Only	The NGSS include knowledge of how speed relates to energy at grade 4 (i.e., the faster an object is moving, the more energy it has). NAEP includes the concepts of motion and speed at grade 4, but the relationship between speed and energy is not included until grade 8 (P08.08, P08.12). *NAEP Science Practice*: Using Science Principles *Cross-grade alignment*: 4-PS3-1 at a higher grade in NAEP
Definitions of Energy Relationship Between Energy and Forces Conservation of Energy and Energy Transfer	4-PS3-3: Ask questions and predict outcomes about the changes in energy that occur when objects collide.	NGSS Only	Only the NGSS include knowledge about the changes in energy that occur as a result of changes in speed when objects collide at grade 4. NAEP includes relating energy to the speed of moving objects at grade 8 (P08.08). Energy transfer during collisions is explicitly included in NAEP at grade 12. *NAEP Science Practice*: Using Science Principles *Cross-grade alignment*: 4-PS3-3 at a higher grade in NAEP
Information Technologies and Instrumentation	4-PS4-3: Generate and compare multiple solutions that use patterns to transfer information.	NGSS Only	Only the NGSS include the concept of using patterns to transfer information. This topic is not included at any grade level in the NAEP framework. *NAEP Science Practice*: Using Technological Design

NAEP Science Content Statements Not Included in the NGSS at Grade 4			
Topic: Subtopic	**Content Statement**	**Similarity Rating**	**Summary Statement**
Matter: Properties of Matter	P04.01: Objects and substances have properties. Weight (mass) and volume are properties that can be measured using appropriate tools.	NAEP Only	NAEP includes physical properties of objects, including weight (mass) and volume that can be measured using appropriate tools at grade 4. Observing and measuring properties of objects is included in the NGSS at grade 2 (2-PS1-1), although quantitative measurements are restricted to length. *Cross-grade alignment*: P04.01 at a lower grade in the NGSS
Matter: Properties of Matter	P04.02: Objects vary in the extent to which they absorb and reflect light and conduct heat (thermal energy) and electricity.	NAEP Only	Only NAEP includes how different objects reflect light, conduct heat, and conduct electricity at grade 4. This topic is included to varying degrees in NGSS at grade 1 – objects made with transparent, translucent, opaque, and reflective materials (1-PS4-3); grade 2 – classifying different materials based on observable properties (2-PS1-1); and grade 5 – observations and measurements to identify materials based on properties, including reflectivity, electrical conductivity, and thermal conductivity (5-PS1-3).
Matter: Properties of Matter	P04.03: Matter exists in several different states; the most common states are solid, liquid, and gas. Each state of matter has unique properties. For instance, gases are easily compressed while solids and liquids are not. The shape of a solid is independent of its container; liquids and gases take the shape of their containers.	NAEP Only	NAEP includes a basic understanding of the states of matter (solid, liquid, and gas) at grade 4. An equivalent performance expectation is not included in the NGSS, but some related concepts are included at varying degrees in grade 2 – classifying different kinds of matter (e.g., liquid or solid) based on observable properties (2-PS1-1); and grade 5 – observations and measurements to identify materials based on properties (5-PS1-3), that the amount of matter does not change when it changes form (5-PS1-2), and the concept of compressibility of gases (5-PS1-1). Although the level of understanding at grade 5 goes beyond the NAEP grade 4 content statement, grade 5 is where gases are first introduced in the NGSS. Gas as a state of matter is not included at grades 2, 3, or 4 in the NGSS. *Cross-grade alignment*: P04.03 at a higher grade in the NGSS
Matter: Properties of Matter	P04.04: Some objects are composed of a single substance; others are composed of more than one substance.	NAEP Only	Only NAEP includes the concept of mixtures and pure substances at grade 4. This concept is included at grade 5 in the NGSS (5-PS1-4), but at a higher level than grade 4 and includes the possibility of mixing producing new substances. *Cross-grade alignment*: P04.04 at a higher grade in the NGSS

Matter: Properties of Matter	P04.05: Magnets can repel or attract other magnets. They can also attract certain nonmagnetic objects at a distance.	NAEP Only	NAEP includes basic knowledge of magnetic properties – magnetic attraction and repulsion between magnets and the attraction of nonmagnetic objects. This topic is included at grade 3 in the NGSS (3-PS2-3, 3-PS2-4). *Cross-grade alignment*: P04.05 at a lower grade in the NGSS
Matter: Changes in Matter	P04.06: One way to change matter from one state to another and back again is by heating and cooling.	NAEP Only	NAEP includes changing states of matter by adding and removing heat. The basic concept of reversible changes (such as liquid to solid) is included at grade 2 in the NGSS (2-PS1-4). Broader expectations related to changes of state are included in the NGSS at grade 5 (5-PS1-2), but the performance expectation is beyond grade 4 in NAEP as it focuses on conservation of weight (mass). *Cross-grade alignment*: P04.06 at a lower grade in the NGSS
Energy: Forms of Energy	P04.08: Heat (thermal energy) results when substances burn, when certain kinds of materials rub against each other, and when electricity flows though wires. Metals are good conductors of heat (thermal energy) and electricity. Increasing the temperature of any substance requires the addition of energy.	NAEP Only	NAEP includes introductory concepts related to heat (thermal energy) and temperature at grade 4, including burning substances, objects rubbing against each other, and electricity flowing through wires. Additionally, NAEP includes knowledge of metals being good conductors of heat, and that an increase in temperature requires the addition of heat (energy). There are no equivalent performance expectations in the NGSS, although thermal and electrical conductivity of metals is included as part of a more general performance expectation about identifying materials based on properties at grade 5 (5-PS1-3). Thermal energy is introduced in the NGSS in middle school, but at a higher level (MS1-PS1-4, MS1-PS1-6).
Motion: Motion at the Macroscopic Level	P04.12: An object's position can be described by locating the object relative to other objects or a background. The description of an object's motion from one observer's view may be different from that reported from a different observer's view.	NAEP Only	Only NAEP includes knowledge of position and how an object's position is defined relative to other objects' positions. While these concepts may be subsumed within NGSS performance expectations at grade 3 related to measuring motion (3-PS2-1, 3-PS2-2), they are not explicit. NAEP also includes introductory concepts related to relative motion based on observers in different positions at grade 4. These concepts are not explicitly included in the NGSS at any grade level.
Motion: Motion at the Macroscopic Level	P04.13: An object is in motion when its position is changing. The speed of an object is defined by how far it travels divided by the amount of time it took to travel that far.	NAEP Only	NAEP includes basic knowledge of motion and speed (distance divided by time) at grade 4. This knowledge may be subsumed under the NGSS performance expectation on the relationship between speed and energy (4-PS3-1), but the definition of motion and speed are not explicitly included in an NGSS performance expectation at grade 4. Measurement of an object's motion is introduced at grade 3 in the NGSS (3-PS2-2).

Motion: Forces Affecting Motion	P04.14: The motion of objects can be changed by pushing or pulling. The size of the change is related to the size of the force (push or pull) and the weight (mass) of the object on which the force is exerted. When an object does not move in response to a push or a pull, it is because another push or pull (friction) is being applied by the environment.	NAEP Only	NAEP includes the effect of the magnitude of push/pull forces and the weight (mass) of objects on motion at grade 4. An introductory understanding of friction as a force opposing the direction of push/pull force is also included. No NGSS performance expectations related to forces and motion are included at grade 4. Comparing the effects of different sizes of push/pull forces on the motion of objects is introduced in kindergarten in the NGSS (K-PS2-1, K-PS2-2). Effects of balanced and unbalanced forces on the motion of objects are included at grade 3 in the NGSS (3-PS2-1). The effect of the mass of objects on motion is included in middle school (MS-PS2-2). Friction as a force opposing motion is not explicitly included in any NGSS performance expectation, although this concept is included in the underlying disciplinary core idea at grade 2. *Cross-grade alignment*: P04.14 at a lower grade in the NGSS
Motion: Forces Affecting Motion	P04.15: Earth pulls down on all objects with a force called gravity. With a few exceptions (helium-filled balloons), objects fall to the ground no matter where the object is on Earth.	NAEP Only	NAEP includes a basic understanding of the force due to gravity on objects on Earth at grade 4. This concept is included at grade 5 in the NGSS (5-PS2-1). *Cross-grade alignment*: P04.15 at a higher grade in the NGSS

Exhibit E-1b. Content comparison of NGSS performance expectations and NAEP science content statements: Physical sciences, middle school/grade 8

NGSS Performance Expectations Grouped with NAEP Science Content Statement(s) at Grade 8			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Structure and Properties of Matter	MS-PS1-1: Develop models to describe the atomic composition of simple molecules and extended structures.	Not Similar	Both the NGSS and NAEP include knowledge of the atomic composition of molecules at grade 8, including models and drawings showing how atoms are linked to make molecules. However, the depth and breadth of content covered is different. The NGSS emphasize a range of molecular complexities, from simple molecules such as ammonia and methanol to extended structures such as salt crystals and diamonds, while NAEP focuses on simple common molecules (e.g., H_2O and CO_2). The focus in NAEP is on the difference between elements and compounds. Neither the NGSS nor NAEP include the concept of valence electrons or subatomic structure at grade 8. *NAEP Content Statement(s)*: P08.04A *NAEP Science Practice*: Using Science Principles
Structure and Properties of Matter Chemical Reactions	MS-PS1-2: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	Similar	Both the NGSS and NAEP include evidence that a chemical reaction has occurred based on changes in physical and chemical properties of substances. The NGSS assessment boundaries are restricted to properties of density, melting point, boiling point, solubility, flammability, and odor. NAEP also includes color change and conductivity. *NAEP Content Statement(s)*: P08.04B, P08.07A *NAEP Science Practice*: Using Scientific Inquiry
Structure and Properties of Matter Definitions of Energy	MS-PS1-4: Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.	Similar	Both the NGSS and NAEP include using a model of the particulate nature of matter to describe, predict, and explain changes of state, particle motion, and temperature in response to the addition or removal of thermal energy. Both frameworks include relating temperature and the different states of matter to the speed and distance between particles. NAEP also includes conservation of mass during physical changes at grade 8, which is introduced at grade 5 in the NGSS (5-PS1-2). *NAEP Content Statement(s):* P08.01, P08.06 *NAEP Science Practice*: Using Science Principles

Chemical Reactions	MS-PS1-5: Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.	Similar	Both the NGSS and NAEP include conservation of mass during chemical change. Both emphasize the law of conservation of matter, including models demonstrating that the number and kinds of atoms in the reactants are the same as those in the products. Neither requires the use of balanced equations. *NAEP Content Statement(s):* P08.07B *NAEP Science Practice*: Using Science Principles
Forces and Motion	MS-PS2-2: Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.	Similar	Both the NGSS and NAEP emphasize a qualitative understanding of Newton's first two laws of motion applied to objects at grade 8. This includes applying the concept of additive forces to predict changes in motion (speed and direction) and the analysis of both unbalanced and balanced forces (object remaining at rest or continuing at constant speed in a straight line). Additionally, both the NGSS and NAEP restrict these analyses of motion to a straight line. NAEP includes the use of force diagrams at grade 8 to represent the relative magnitude and direction of forces, but the NGSS do not explicitly state whether or not this is included. The NGSS include that motion depends on both the magnitude of forces as well as the mass of the object. This concept is introduced in NAEP at grade 4 (P04.14). *NAEP Content Statement(s):* P08.16 *NAEP Science Practice*: Using Scientific Inquiry
Types of Interactions	MS-PS2-4: Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.	Similar	Both NAEP and the NGSS include gravitational force between two masses at grade 8. The NGSS performance expectation in physical sciences includes application to the motion of bodies in the solar system. NAEP includes relevant content statements in both physical science (P08.15) and Earth and space sciences (E08.02). Neither the NGSS nor NAEP include knowledge of Newton's Law of Gravitation or Kepler's laws. Newton's Law of Gravitation is included at grade 12 in both the NGSS and NAEP. *NAEP Content Statement(s):* P08.15, E08.02 *NAEP Science Practice*: Using Science Principles

Types of Interactions	MS-PS2-5: Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.	Not Similar	The NGSS and NAEP include the concept of electric and magnetic forces. The focus of the NGSS is to provide evidence that fields exist between objects. Although NAEP includes forces that act at a distance (electric, magnetic, and gravitational) at grade 8, there is not a focus on force fields in physical science at any grade. In Earth and space sciences, NAEP does include a content statement related to Earth's magnetic field at grade 8 (E08.10). *NAEP Content Statement(s):* P08.15 *NAEP Science Practice*: Using Scientific Inquiry
Definitions of Energy	MS-PS3-1: Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.	Not Similar	Both the NGSS and NAEP include the concept of kinetic energy and emphasize a general understanding based on observations in familiar situations (e.g., a moving baseball hitting a window, riding a bicycle at different speeds). However, the NGSS explicitly include the relationship of kinetic energy to both the speed and the mass of objects. This is not included in NAEP at grade 8; the formula for kinetic energy is expected at grade 12. *NAEP Content Statement(s):* P08.08 *NAEP Science Practice*: Using Science Principles
Definitions of Energy Relationship Between Energy and Forces	MS-PS3-2: Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.	Similar	Both the NGSS and NAEP include the concept of potential energy, but there are some differences in the focus and scope. NAEP focuses on three different forms of potential energy (gravitational, elastic, and chemical). The NGSS focus on the general concept of potential energy in a system of objects, depending on their relative positions. Assessment boundaries in the NGSS are restricted to electric, magnetic, and gravitational interactions. *NAEP Content Statement(s):* P08.09 *NAEP Science Practice*: Using Science Principles
Definitions of Energy Conservation of Energy and Energy Transfer	MS-PS3-3: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.	Similar	Both the NGSS and NAEP include the concept of thermal energy transfer. This NGSS performance expectation requires students to evaluate a design based on its ability to insulate or conduct heat. This could also be assessed in NAEP through the integration of content with the practice of Using Technological Design. *NAEP Content Statement(s):* P08.10A *NAEP Science Practice*: Using Technological Design

Definitions of Energy Conservation of Energy and Energy Transfer	MS-PS3-4: Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.	Not Similar	Both the NGSS and NAEP include knowledge of the particulate nature of matter and the relationship between temperature and the motion of particles at grade 8. However, the NGSS explicitly include the connection between temperature and the average kinetic energy of particles and the relationship between temperature and mass of a sample during thermal energy transfer. These aspects of the NGSS performance expectation are not explicitly included in NAEP until grade 12 (P12.05, P12.12). At grade 8, NAEP focuses on differences in particle motion (e.g., speed, distance between particles) as a result of thermal energy transfer during physical changes. *NAEP Content Statement(s):* P08.06 *NAEP Science Practice*: Using Scientific Inquiry
Conservation of Energy and Energy Transfer	MS-PS3-5: Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.	Similar	Both the NGSS and NAEP include the concept of energy conservation and that as one form of energy in a system increases, other forms of energy decrease. The NGSS emphasize evidence of energy transfer resulting in changes in kinetic energy of objects, such as temperature change or motion. NAEP explicitly includes other types of energy transformations (e.g., kinetic and gravitational potential energy of falling objects). *NAEP Content Statement(s):* P08.12 *NAEP Science Practice*: Using Science Principles
Wave Properties	MS-PS4-1: Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.	Not Similar	Although both the NGSS and NAEP include knowledge of waves and the concept that waves have energy and transfer energy, there are major differences in emphasis. The NGSS focus on how the amplitude of a wave is related to the amount of energy it contains and emphasize both qualitative and quantitative reasoning about waves. NAEP's treatment of waves at grade 8 is qualitative in nature and does not focus specifically on amplitude. NAEP more generally includes what waves are, what causes them, and the different types of waves (sound and seismic waves, waves on water, and light waves). Some of these principles are included in grade 4 in the NGSS (4-PS4-1). Quantitative measures of wave amplitudes are not included in NAEP until grade 12. Neither the NGSS nor NAEP focuses on properties of electromagnetic waves until grade 12. *NAEP Content Statement(s):* P08.10B *NAEP Science Practice*: Using Science Principles

Wave Properties Electromagnetic Radiation	MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.	Not Similar	Both the NGSS and NAEP include the interaction of waves with matter at grade 8, but the focus is different. Both the NGSS and NAEP include light and mechanical waves, such as sound and water waves. The NGSS emphasize the different ways in which these waves interact with matter (reflection, absorption, and transmission). Concepts related to the behavior of light are introduced at a basic level at grade 4 in NAEP (P04.09). At grade 8, NAEP is focused on the transfer of energy by waves. *NAEP Content Statement(s):* P08.10 *NAEP Science Practice*: Using Science Principles
NGSS Performance Expectations Not Included in NAEP Science at Grade 8			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Structure and Properties of Matter Chemical Reactions	MS-PS1-3: Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.	NGSS Only	Only the NGSS include knowledge in grade 8 physical science that artificial, man-made materials come from natural materials and an awareness of how these materials affect society. The emphasis in the NGSS is that these natural materials undergo a chemical change in order to form a synthetic material. Human use of Earth materials (natural or modified) is included at grade 4 in NAEP in Earth and space sciences (E04.06), but there are no expectations related to chemical processes at grade 4. The concept of humans using natural materials in various ways is also addressed in NAEP at grades 4 and 8 in biogeochemical cycles (E04.10, E04.11, E08.15); however, these content statements focus on humans' impact on the environment instead of the technology aspect that the NGSS performance expectation focuses on. *NAEP Science Practice*: Identifying Science Principles
Chemical Reactions	MS-PS1-6: Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.	NGSS Only	The NGSS include technological design applications of chemical reactions that release or absorb thermal energy at grade 8. Although release of heat or temperature change may be included as evidence of chemical change at grade 8, the concept of exothermic and endothermic reactions is included in NAEP at grade 12 (P12.14). *NAEP Science Practice*: Using Technological Design *Cross-grade alignment*: MS-PS1-6 at a higher grade in NAEP

Forces and Motion	MS-PS2-1: Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.	NGSS Only	The NGSS include technological design applications of Newton's Third Law to solve a problem involving two objects colliding. Knowledge of Newton's Third Law, specifically involving collisions, is not included in NAEP until grade 12 (P12.21). *NAEP Science Practice*: Using Technological Design *Cross-grade alignment*: MS-PS2-1 at a higher grade in NAEP
Types of Interactions	MS-PS2-3: Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.	NGSS Only	The NGSS include factors that affect the strength of electric and magnetic forces at grade 8. At grade 8, NAEP includes conceptual understanding that magnetic and electrical forces can act at a distance, but quantitative factors related to electric force (e.g., relationship to the magnitude of charge and distance) are included in NAEP at grade 12 (P12.23). Basic knowledge of magnets, magnetic attraction/repulsion and electromagnets is included in NAEP at grade 4 (P04.05, P04.11), but factors affecting the strength of magnetic force are not explicitly included in at any grade. *NAEP Science Practice*: Using Scientific Inquiry *Cross-grade alignment*: MS-PS2-3 at a higher grade in NAEP
Information Technologies and Instrumentation	MS-PS4-3: Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.	NGSS Only	Only the NGSS include digital signals as a method for transmitting and encoding information. The NGSS include this concept to exemplify how waves can be used for communication purposes. Knowledge relating to information transmission by waves is not included in NAEP in any grade. *NAEP Science Practice*: Using Science Principles

NAEP Science Content Statements Not Included in the NGSS in Middle School			
Topic: Subtopic	**Content Statement**	**Similarity Rating**	**Summary Statement**
Matter: Properties of Matter	P08.02: Chemical properties of substances are explained by the arrangement of atoms and molecules.	NAEP Only	NAEP includes understanding that chemical properties of substances are explained by the arrangement of atoms and molecules at grade 8. There is no corresponding performance expectation in the NGSS at grade 8. This concept is more consistent with expectations in a high school topic in the NRC K-12 framework (HS-PS1-A) relating the structure and interactions of matter to forces within and between atoms. There is a related NGSS performance expectation at grade 12 (HS-PS1-3). *Cross-grade alignment*: P08.02 at a higher grade in the NGSS
Matter: Properties of Matter	P08.03: All substances are composed of 1 or more of approximately 100 elements. The periodic table organizes the elements into families of elements with similar properties.	NAEP Only	Only NAEP includes understanding and using the periodic table at grade 8. Use of the periodic table is not included until grade 12 in the NGSS (HS-PS1-1). *Cross-grade alignment*: P08.03 at a higher grade in the NGSS
Matter: Properties of Matter	P08.05: Substances are classified according to their physical and chemical properties. Metals and acids are examples of such classes. Metals are a class of elements that exhibit common physical properties such as conductivity and common chemical properties such as reacting with nonmetals to produce salts. Acids are a class of compounds that exhibit common chemical properties, including a sour taste, characteristic color changes with litmus and other acid/base indicators, and the tendency to react with bases to produce a salt and water.	NAEP Only	NAEP includes the classification of substances based on physical and chemical properties, with a focus on metals and acids and bases at grade 8. The NGSS include identifying materials based on physical properties in grade 5 (5-PS1-3), but there is no performance expectation related to chemical and physical properties of metals or acids and bases at grade 8. Knowledge of chemical properties of elements (including metals) is included at grade 12 in the NGSS (HS-PS1-1, HS-PS1-2), but acids and bases are not included. *Cross-grade alignment*: P08.05 at a higher grade in the NGSS
Energy: Forms of Energy	P08.11: A tiny fraction of the light energy from the Sun reaches Earth. Light energy from the Sun is Earth's primary source of energy, heating Earth surfaces and providing the energy that results in wind, ocean currents, and storms.	NAEP Only	Only NAEP includes knowledge of the Sun as an energy source and its effect on Earth's surface, materials, and processes in physical science at grade 8. Related content is included in Earth and space sciences in both NAEP (E08.11) and the NGSS (MS-ESS2-6).

Energy: Energy Transfer and Conservation	P08.13: Nuclear reactions take place in the Sun. In plants, light from the Sun is transferred to oxygen and carbon compounds, which, in combination, have chemical potential energy (photosynthesis).	NAEP Only	Only NAEP includes knowledge that the source of light energy for photosynthesis is nuclear reactions in the Sun in physical science at grade 8, although detailed knowledge of nuclear fusion is not expected. The role of nuclear fusion in the release of energy from the Sun is not included in the NGSS until grade 12 (HS-ESS1-1). Concepts related to plants using light energy to produce sugars during photosynthesis is included in life sciences in both the NGSS (MS-LS1-6) and NAEP (L08.04), but the transformation of light energy to chemical potential energy is explicit only in the physical science content statement in NAEP. *Cross-grade alignment*: P08.13 at a higher grade in the NGSS
Motion: Motion at the Macroscopic Level	P08.14: An object's motion can be described by its speed and the direction in which it is moving. An object's position can be measured and graphed as a function of time. An object's speed can be measured and graphed as a function of time.	NAEP Only	NAEP includes a focus on qualitative and quantitative descriptions of motion in terms of speed and direction and on using and interpreting motion graphs at grade 8 (position versus time and speed versus time). Although these concepts may be subsumed within performance expectations related to motion (MS-PS2-1, MS-PS2-2), there is no comparable emphasis in the NGSS at grade 8. Velocity versus time graphs are included in a NGSS performance expectation in high school (HS-PS1-1), but the focus is on the quantitative application of Newton's second law, which is not included at grade 8 in either NAEP or the NGSS.

Exhibit E-1c. Content comparison of NGSS performance expectations and NAEP science content statements: Physical sciences, high school/grade 12

NGSS Performance Expectations Grouped with NAEP Science Content Statement(s) at Grade 12			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Structure and Properties of Matter Types of Interactions	HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.	Similar	Both the NGSS and NAEP include knowledge of the periodic table and how the table is organized to show patterns among the properties of elements. Both explicitly include that the elements are organized based on their atomic number (i.e. the number of protons in a neutral atom of each element). The NGSS include knowledge that the horizontal organization of elements in the periodic table by atomic number reflects patterns of outermost electrons. The NGSS and NAEP also include knowledge that various chemical properties of atoms (e.g., reactivity, types, and number of bonds that can form) are determined by the number and configuration of the outermost electrons of each element. *NAEP Content Statement(s):* P12.03, P12.06 *NAEP Science Practice*: Using Science Principles
Structure and Properties of Matter Chemical Reactions	HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.	Similar	Both the NGSS and NAEP include explanations of chemical reactions based on the electronic structure of the reactants and knowledge of patterns among elements in the periodic table. Both specifically include knowledge of common chemical reactions that involve carbon bonding with itself or with either oxygen or hydrogen. The NGSS are limited to combustion reactions and main-group elements. NAEP touches on organic chemistry, discussing the various structures that form with carbon atoms (e.g., rings, chains, and branching networks). NAEP also includes reactions of carbon with nitrogen and sulfur and includes knowledge of polymers, oils, and large molecules that are essential to life. *NAEP Content Statement(s):* P12.03, P12.06, P12.07 *NAEP Science Practice*: Using Science Principles
Structure and Properties of Matter Types of Interactions	HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.	Similar	Both the NGSS and NAEP include knowledge of how the arrangement and strength of the force between ions, atoms, and molecules affect the physical properties of substances. Physical properties included in both are the melting point and the boiling point. NAEP also includes a qualitative understanding of the conductivity of heat and electricity, and solubility. *NAEP Content Statement(s):* P12.01 *NAEP Science Practice*: Using Scientific Inquiry

Structure and Properties of Matter Chemical Reactions	HS-PS1-4: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.	Not Similar	Both the NGSS and NAEP include knowledge of endothermic and exothermic reactions and that energy is conserved during these reactions. The NGSS focus on bond energy and how bond energy changes during the reaction process, but does not include a quantitative analysis of bond energy changes. The topic of bond energy changes is not included in NAEP at any grade. *NAEP Content Statement(s):* P12.14, P12.16 *NAEP Science Practice*: Using Science Principles
Nuclear Processes	HS-PS1-8: Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.	Similar	Both the NGSS and NAEP include knowledge that fission and fusion involve changes in the composition of the nuclei of atoms and the release of energy. Additionally, they both include knowledge of alpha, beta, and gamma particles. The NGSS include radioactive decay, which is not explicitly included in the NAEP physical science content statement. Radioactive decay is included in the Earth and space sciences content area of NAEP, but is limited to decay as a source of internal energy for the Earth (E12.09) and radiocarbon dating (E12.04). NAEP emphasizes knowledge that nuclear reactions convert small amounts of matter into large amounts of energy, which is also expected in the NGSS. *NAEP Content Statement(s):* P12.11, P12.15 *NAEP Science Practice*: Using Science Principles
Forces and Motion	HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.	Similar	Both the NGSS and NAEP include Newton's second law, defined as the mathematical relationship $F = ma$ relating the force applied to an object to its mass and acceleration. NAEP also explicitly includes content statements related to Newton's first law (motion of an object changes only when a net force is applied) and descriptions/interpretations of the motion of objects (position, velocity, and acceleration). These concepts are also assumed as underlying understandings for the NGSS performance expectation. The NGSS limit assessment to one-dimensional motion, while NAEP may include interpreting motion along a curvilinear path. In NAEP, demonstrating a qualitative or semi-quantitative understanding of the law (e.g., proportionality) is considered more important than calculating quantities using mathematical relationships. *NAEP Content Statement(s):* P12.17, P12.19, P12.20 *NAEP Science Practice*: Using Scientific Inquiry

Forces and Motion	HS-PS2-2: Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.	Similar	Both the NGSS and NAEP include the law of conservation of momentum. Additionally, both make a connection to Newton's second law in that momentum within a system can only be conserved when there is no net force acting on the system. Both assessments limit the analysis of momentum conservation to one dimension. *NAEP Content Statement(s):* P12.21 *NAEP Science Practice*: Using Science Principles
Forces and Motion	HS-PS2-3: Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.	Similar	Both the NGSS and NAEP include the concept of Newton's third law. Specifically, they both address that when two objects interact, the forces they exert on each other are equal and momentum is conserved in a closed system. The NGSS performance expectation applies these concepts in a technological design context to minimize the force on an object during a collision. *NAEP Content Statement(s):* P12.21 *NAEP Science Practice*: Using Technological Design
Types of Interactions	HS-PS2-4: Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	Similar	Both the NGSS and NAEP include knowledge of gravitational and electric forces between objects. The NGSS emphasize both conceptual and quantitative descriptions of these forces, while NAEP focuses on a qualitative or semi-quantitative understanding (e.g., the magnitudes of these forces are inversely proportional to the square of the distance between the objects and proportional to the objects' masses or charges). NAEP includes calculations of gravitational potential energy ($E = mgh$), but does not focus on calculations of the force due to gravity. *NAEP Content Statement(s):* P12.22, P12.23 *NAEP Science Practice*: Using Science Principles
Structure and Properties of Matter Types of Interactions	HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.	Not Similar	Both the NGSS and NAEP include knowledge of molecular-level structure and how it affects a substance's physical and chemical properties. However, NAEP does not explicitly include how the structure of substances affects the functioning of designed materials. *NAEP Content Statement(s):* P12.01 *NAEP Science Practice*: No Primary NAEP Science Practice

Definitions of Energy Conservation of Energy and Energy Transfer	HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.	Not Similar	Both the NGSS and NAEP include the concept that total energy is conserved in a closed system. However, NAEP does not focus on quantitative calculations of the changes in energy of components of a system that considers energy flows in and out of the system. *NAEP Content Statement(s):* P12.16 *NAEP Science Practice*: Using Science Principles
Definitions of Energy	HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).	Similar	Both the NGSS and NAEP include the concepts of kinetic and potential energy as components of the total energy in a system. The NGSS emphasize the connection between the motion and relative position of particles and objects to energy at the macroscopic scale. NAEP includes separate content statements related to the energy of particles at the microscopic scale (translational, rotational, and vibrational) and changes between kinetic and potential energy of macroscopic objects. *NAEP Content Statement(s):* P12.12A, P12.13 *NAEP Science Practice*: Using Science Principles
Definitions of Energy Energy in Chemical Processes and Everyday Life	HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.	Not Similar	Both the NGSS and NAEP include the concepts of energy conservation in a system and energy transformation. However, this NGSS performance expectation requires designing, building, and refining a device that converts energy and considers constraints such as efficiency. This application goes beyond the expectations in NAEP, even in a technological design context. *NAEP Content Statement(s):* P12.16 *NAEP Science Practice*: Using Technological Design

Conservation of Energy and Energy Transfer Energy in Chemical Processes and Everyday Life	HS-PS3-4: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	Not Similar	Both the NGSS and NAEP include the concepts of energy transfer and conservation in a closed system, thermal equilibrium, and temperature as a measure of thermal energy; however, there is a difference in focus and the level of expectations. NAEP focuses on the concept of specific heat, temperature and thermal energy changes associated with physical changes, calculations of changes in temperatures in closed systems (e.g., final temperature of a mixture of two liquids of different temperatures and volumes), and conceptual understanding of temperature differences at the microscopic scale. The NGSS emphasize both conceptual and quantitative descriptions of energy transfer and the uniformity of energy distribution in a system (second law of thermodynamics), which is not explicit in NAEP. *NAEP Content Statement(s):* P12.05, P12.12A, P12.16 *NAEP Science Practice*: Using Scientific Inquiry
Relationship Between Energy and Forces	HS-PS3-5: Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	Not Similar	The NGSS include models of objects interacting through electric and magnetic fields and changes in energy due to the interaction. NAEP includes knowledge of electric force at grade 12, which overlaps part of the NGSS performance expectation, but does not emphasize fields or changes in energy, which is the focus in the NGSS. Magnetic force is not included in NAEP at grade 12. *NAEP Content Statement(s):* P12.23 *NAEP Science Practice*: Using Science Principles
Wave Properties	HS-PS4-1: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.	Similar	Both the NGSS and NAEP include quantitative analysis of the relationships between frequency, wavelength, and velocity of waves. The NAEP content statement is specific to electromagnetic waves, while the NGSS include other types of waves. NAEP additionally includes amplitude and the relationship between energy and frequency of waves. *NAEP Content Statement(s):* P12.10A *NAEP Science Practice*: Using Science Principles

Wave Properties Electromagnetic Radiation	HS-PS4-3: Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.	Not Similar	Both the NGSS and NAEP include properties of electromagnetic radiation, but the focus is different. The NGSS emphasize evidence for the dual wave/particle model of electromagnetic radiation (e.g., resonance, interference, diffraction, and photoelectric effect). NAEP focuses on how electromagnetic waves are produced by moving electric charges or changing magnetic fields and that the energy of electromagnetic waves is transferred to matter in packets. However, NAEP does not explicitly include an evaluation of the dual particle/wave model. *NAEP Content Statement(s):* P12.10 *NAEP Science Practice*: Using Science Principles
Electromagnetic Radiation	HS-PS4-4: Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.	Not Similar	Both the NGSS and NAEP include knowledge that the energy of electromagnetic radiation is a function of frequency and that electromagnetic waves transfer energy to matter. The NGSS extend this to include effects that different frequencies of electromagnetic radiation have when absorbed by matter, which is not explicit in NAEP. *NAEP Content Statement(s):* P12.10 *NAEP Science Practice*: Using Science Principles

NGSS Performance Expectations Not Included in NAEP Science at Grade 12			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Chemical Reactions	HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.	NGSS Only	Only the NGSS include knowledge of rates of chemical reactions and how temperature and the concentration of the reactants can affect this rate. NAEP does not include this content at any grade level. *NAEP Science Practice*: Using Science Principles
Chemical Reactions	HS-PS1-6: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.	NGSS Only	Only the NGSS include changing the design of a chemical system to produce more products at equilibrium. The emphasis is on the application of Le Chatelier's principle. NAEP does not include the concept of chemical equilibrium at any grade level. *NAEP Science Practice*: Using Technological Design
Chemical Reactions	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	NGSS Only	Only the NGSS include using mathematical representations to show that atoms and mass are conserved during a chemical reaction (e.g., using the concept of moles to convert from atomic to macroscopic scale). NAEP includes the conservation of atoms and mass during chemical reactions at grade 8 (P08.07), but does not include quantitative analysis. *NAEP Science Practice*: Using Science Principles *Cross-grade alignment*: HS-PS1-7 at a lower grade in NAEP
Types of Interactions Definitions of Energy	HS-PS2-5: Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.	NGSS Only	Only the NGSS include the concept of electromagnetic induction (electric current produced by changing magnetic fields and magnetic fields produced by moving electrical charges). Electromagnetic induction is not included in NAEP at grade 12, although very basic knowledge is included at grade 4 (P04.11) that magnetic effects are produced by electricity flowing through wires. *NAEP Science Practice*: Using Scientific Inquiry
Wave Properties	HS-PS4-2: Evaluate questions about the advantages of using a digital transmission and storage of information.	NGSS Only	Only the NGSS include knowledge of the advantages of digital transmission over analog transmission and how to store digital information. NAEP does not include this content at any grade. *NAEP Science Practice*: Using Technological Design

Energy in Chemical Processes and Everyday Life Wave Properties Electromagnetic Radiation Information Technologies and Instrumentation	HS-PS4-5: Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.	NGSS Only	Only the NGSS explicitly include knowledge of how technological devices use wave properties to transmit and capture information and energy. NAEP includes properties of electromagnetic waves at grade 12 (P12.10). This includes the transfer of energy to matter, but does not explicitly include the transfer of energy to capture information. However, some assessment items in NAEP might be developed related to this topic through the practice of Using Technological Design. *NAEP Science Practice*: Using Technological Design

NAEP Science Content Statements Not Included in the NGSS in High School			
Topic: Subtopic	**Content Statement**	**Similarity Rating**	**Summary Statement**
Matter: Properties of Matter	P12.02: Electrons, protons, and neutrons are parts of the atom and have measurable properties, including mass and, in the case of protons and electrons, charge. The nuclei of atoms are composed of protons and neutrons. A kind of force that is only evident at nuclear distances holds the particles of the nucleus together against the electrical repulsion between the protons.	NAEP Only	Only NAEP emphasizes the structure of the atom and knowledge of subatomic particles at grade 12, including the strong nuclear force that holds particles of the nucleus together. Although the disciplinary core ideas in the NRC K-12 framework include knowledge of subatomic particles at grade 12, there is no NGSS performance expectation related specifically to assessing basic knowledge of atomic structure. Knowledge of the nuclear force is not specified in the NGSS.
Matter: Properties of Matter	P12.04: In a neutral atom, the positively charged nucleus is surrounded by the same number of negatively charged electrons. Atoms of an element whose nuclei have different numbers of neutrons are called isotopes.	NAEP Only	Only NAEP includes the subatomic structure of neutral atoms and the concept of isotopes at grade 12. While the subatomic structure of atoms is included in the disciplinary core ideas in the NRC K-12 framework, there is no explicit performance expectation in the NGSS comparable to this content statement in NAEP.
Energy: Forms of Energy	P12.08: Atoms and molecules that compose matter are in constant motion (translational, rotational, or vibrational).	NAEP Only	Only NAEP emphasizes the different types of particle motion in matter (translational, rotational, or vibrational) at grade 12. Although the NGSS include the relationship between energy and particle motion at both grade 8 (MS-PS1-4) and grade 12 (HS-PS3-2), the three types of particle motion are not explicitly included in the NGSS.
Energy: Forms of Energy	P12.09: Energy may be transferred from one object to another during collisions.	NAEP Only	Only NAEP explicitly includes energy transfer during collisions at grade 12. At grade 12, the NGSS focus on forces and changes in momentum during collisions (HS-PS2-3), but not changes in energy. Knowledge that a change in the kinetic energy of an object means that energy was transferred to or from the object is included in the NGSS at middle school (MS-PS3-5). *Cross-grade alignment*: P12.09 at a lower grade in the NGSS

Energy: Energy Transfer and Conservation	P12.12B (2nd part): Heating increases the translational, rotational, and vibrational energy of the atoms composing elements and the molecules or ions composing compounds. As the translational energy of the atoms, molecules, or ions increases, the temperature of the matter increases. Heating a sample of a crystalline solid increases the vibrational energy of the atoms, molecules, or ions. When the vibrational energy becomes great enough, the crystalline structure breaks down and the solid melts. *Note: P12.12B is the second part of the NAEP content statement P12.12. The first part that is grayed out (P12.12A) was grouped with NGSS performance expectation HS-PS3-2 and rated as similar.*	NAEP Only	Only NAEP includes relating the process of melting to the increase in vibrational energy of particles in solids resulting in the breakdown of the crystalline structure at grade 12. Although the NGSS include understanding of particle motion in response to thermal energy transfer, there is no focus on vibrational motion of particles in solids.
Motion: Motion at the Macroscopic Level	P12.18: Objects undergo different kinds of motion (translational, rotational, and vibrational).	NAEP Only	Only NAEP explicitly includes understanding the different types of motion of macroscopic objects (translational, rotational, and vibrational) at grade 12. This content is not a focus in the NGSS at any grade level.

Exhibit E-2a. Content comparison of NGSS performance expectations and NAEP science content statements: Life sciences, grade 4

NGSS Performance Expectations Grouped with NAEP Science Content Statement(s) at Grade 4			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Structure and function	4-LS1-1: Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.	Similar	Both the NGSS and NAEP include organism structures and functions at the fourth-grade level. NAEP addresses these concepts in the context of basic physical needs (food, water, air, waste disposal, energy, and building materials for growth and repair) and survival in different environments. The NGSS explicitly describe the connection between an organism's structure and physical requirements and its growth, behavior, and reproduction. Both the NGSS and NAEP are restricted to macroscopic structures. NAEP also excludes internal structures. *NAEP Content Statement(s):* L04.01, L04.02, L04.07A *NAEP Science Practice*: Using Science Principles
NGSS Performance Expectations Not Included in NAEP Science at Grade 4			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Information processing	4-LS1-2: Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.	NGSS only	Only the NGSS include the function of senses and brain processing at fourth grade. The topic is not included at any grade level in the NAEP framework. *NAEP Science Practice*: Using Science Principles
NAEP Science Content Statements Not Included in the NGSS at Grade 4			
Topic: Subtopic	**Content Statement**	**Similarity Rating**	**Summary Statement**
Structures and Functions of Living Systems: Interdependence	L04.03: Organisms interact and are interdependent in various ways, including providing food and shelter to one another. Organisms can survive only in environments in which their needs are met. Some interactions are beneficial; others are detrimental to the organism and other organisms.	NAEP Only	Only NAEP includes the interdependence of organisms at the fourth-grade level. The NRC K-12 framework includes interdependent relationships in ecosystems in the 3-5 grade band, but the NGSS does not include specific performance expectations measuring these concepts at grade 4. The NGSS include performance expectations related to interdependence at grade 5 (5-LS2-1) and middle school (MS-LS2-2). *Cross-grade alignment*: L04.03 at a higher grade in the NGSS
Structures and Functions of Living Systems: Interdependence	L04.04: When the environment changes, some plants and animals survive and reproduce; others die or move to new locations.	NAEP Only	Only NAEP includes how changes in the environment can affect the organisms living there at grade 4. These concepts are included at grade 3 in the NGSS (3-LS4-3, 3-LS4-4). *Cross-grade alignment*: L04.04 at a lower grade in the NGSS

Changes in Living Systems: Heredity and Reproduction	L04.05: Plants and animals have life cycles. Both plants and animals begin life and develop into adults, reproduce, and eventually die. The details of this life cycle are different for different organisms.	NAEP Only	NAEP includes life cycles at grade 4. In the NGSS this concept is included at grade 3 (3-LS1-1), with essentially the same content expectations as the grade 4 NAEP content statement. *Cross-grade alignment*: L.04.05 at a lower grade in the NGSS
Changes in Living Systems: Heredity and Reproduction	L04.06: Plants and animals closely resemble their parents.	NAEP Only	NAEP includes introductory concepts related to inheritance of physical characteristics from parents to offspring at grade 4 (that plants and animals closely resemble their parents). These concepts are included in the NGSS at grade 1 (1-LS3-1). *Cross-grade alignment*: L04.06 at a lower grade in the NGSS
Changes in Living Systems: Evolution and Diversity	L04.07B (2nd part): Different kinds of organisms have characteristics that enable them to survive in different environments. Individuals of the same kind differ in their characteristics, and sometimes the differences give individuals an advantage in surviving and reproducing. *Note: L04.07B is the second part of the NAEP content statement L04.07. The first part that is grayed out (L04.07A) was grouped with NGSS performance expectation 4-LS1-1 and rated as similar.*	NAEP Only	NAEP includes introductory concepts related to natural selection at grade 4: variation in characteristics within a species and the resulting advantages in survival and reproduction. These concepts are introduced in the NRC K-12 framework in the 3-5 grade band and are included in the NGSS at grade 3 (3-LS4-2). *Cross-grade alignment*: L04.07B at a lower grade in the NGSS

Exhibit E-2b. Content comparison of NGSS performance expectations and NAEP science content statements: Life sciences, middle school/grade 8

NGSS Performance Expectations Grouped with NAEP Science Content Statement(s) at Grade 8			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Structure and Function	MS-LS1-1: Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.	Similar	Both the NGSS and NAEP include knowledge that all living organisms are made of cells as well as the distinction between single-celled and multicellular organisms. NAEP includes additional detail related to the make-up of cells as two-thirds water, which gives cells many of their properties. *NAEP Content Statement(s):* L08.01A *NAEP Science Practice*: Using Scientific Inquiry
Structure and Function	MS-LS1-2: Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.	Not Similar	Cellular function is included at grade 8 in both the NGSS and NAEP. However, the NGSS require more in-depth knowledge of the specific parts of a cell. Cell organelles are excluded in NAEP. *NAEP Content Statement(s):* L08.03A *NAEP Science Practice*: Using Science Principles
Structure and Function	MS-LS1-3: Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.	Similar	Both the NGSS and NAEP expect grade 8 students to understand the concept of cells, tissues, organs, and organ systems that work together to perform essential functions in multicellular organisms (e.g., circulatory, excretory, digestive, and respiratory systems). There are some differences in focus: NAEP includes specific organs and organ systems, while the NGSS explicitly do not include one system independent of others. NAEP emphasizes the role of specialized cells, while the NGSS have a more macroscopic perspective. *NAEP Content Statement(s):* L08.01B *NAEP Science Practice*: Using Science Principles
Growth and Development of Organisms	MS-LS1-4: Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.	Similar	Both the NGSS and NAEP include how certain traits can provide advantages for the reproduction and survival of organisms. The NGSS performance expectation focuses on how animal behaviors and plant structures can affect successful reproduction, while the NAEP objective also includes the effect of environmental change on survival and reproduction. *NAEP Content Statement(s):* L08.11A *NAEP Science Practice*: Using Science Principles

Growth and Development of Organisms	MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.	Similar	The NGSS and NAEP expect students at grade 8 to demonstrate an understanding that both environmental and genetic factors influence the characteristics and growth of organisms. *NAEP Content Statement(s):* L08.10 *NAEP Science Practice*: Using Science Principles
Organization for Matter and Energy Flow in Organisms Energy in Chemical Processes and Everyday Life	MS-LS1-6: Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.	Similar	Both the NGSS and NAEP include an understanding of the role of photosynthesis in plants and the ability to trace the transformations of matter and the flow of energy through organisms. *NAEP Content Statement(s):* L08.04 *NAEP Science Practice*: Using Science Principles
Organization for Matter and Energy Flow in Organisms Energy in Chemical Processes and Everyday Life	MS-LS1-7: Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.	Not Similar	Both the NGSS and NAEP include an understanding that food is broken down to provide energy for cells and is the source of materials for other types of molecules needed for growth. However, there appears to be a greater focus in the NGSS on the atomic/molecular level and the chemical reactions involved. NAEP is at a more macroscopic level, including the role of different organisms (e.g., producers, consumers, and decomposers) in the transformation of matter and flow of energy. *NAEP Content Statement(s):* L08.03B, L08.04, L08.05 *NAEP Science Practice*: Using Science Principles
Interdependent Relationships in Ecosystems	MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.	Similar	Both the NGSS and NAEP include an understanding that resource availability is a determining factor in population size. The NAEP content statement explicitly differentiates between biotic resources and abiotic factors. Although this is not stated in the NGSS performance expectation, it is included in the underlying disciplinary core idea. *NAEP Content Statement(s):* L08.07 *NAEP Science Practice*: Using Scientific Inquiry
Interdependent Relationships in Ecosystems	MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.	Similar	Both the NGSS and NAEP include patterns of interactions between organisms in a variety of ecosystems (e.g., producer/consumer, predator/prey, parasite/host, competitive, and mutually beneficial). The NGSS performance expectation explicitly includes the consideration of abiotic components of ecosystems as well. *NAEP Content Statement(s):* L08.06 *NAEP Science Practice*: Identifying Science Principles

Cycle of Matter and Energy Transfer in Ecosystems	MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.	Not Similar	Though both the NGSS and NAEP include the cycling of matter and flow of energy in ecosystems at grade 8, there is a different focus. NAEP focuses more on the role of organisms, rather than the conservation of matter and flow of energy, which is the focus of the NGSS performance expectation. The NGSS also explicitly include nonliving parts of the ecosystem. *NAEP Content Statement(s):* L08.04, L08.05 *NAEP Science Practice*: Using Science Principles
Ecosystem Dynamics, Functioning, and Resilience	MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.	Similar	Both the NGSS and NAEP include the impact of environmental changes on populations of organisms in an ecosystem. In NAEP, this topic is included in both life science and Earth and space sciences (biogeochemical cycles) as crosscutting content that includes both natural and human-made changes to environments. *NAEP Content Statement(s):* L08.07, L08.08, E08.15 *NAEP Science Practice*: Using Scientific Inquiry
Ecosystem Dynamics, Functioning, and Resilience Biodiversity and Humans	MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services.	Not Similar	Biodiversity is the focus of this NGSS performance expectation and the corresponding NRC K-12 framework disciplinary core idea. Although NAEP includes changes in the environment that affect populations or organisms, it does not explicitly include the need to maintain biodiversity. *NAEP Content Statement(s):* L08.08 *NAEP Science Practice*: Using Technological Design
Growth and Development of Organisms Inheritance of Traits Variation of Traits	MS-LS3-2: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.	Not Similar	Both the NGSS and NAEP include sexual and asexual reproduction at grade 8. However, there are differences in focus and the level of expectations. The NGSS include models such as Punnett squares, whereas Mendelian genetics and dominant/recessive traits are specifically excluded in NAEP. In addition, the emphasis in the NGSS is on the implications for genetic variation, which is not a focus until grade 12 in NAEP (L12.10). *NAEP Content Statement(s):* L08.09 *NAEP Science Practice*: Using Science Principles *Cross-grade alignment*: MS-LS3-2 at a higher grade in NAEP

Evidence of Common Ancestry and Diversity	MS-LS4-1: Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.	Not Similar	Both the NGSS and NAEP stress the use of fossils as evidence for the change in organisms over time. Both frameworks explicitly include extinction, though NAEP has more emphasis on it. NAEP also focuses on fossil evidence of how both life and environmental conditions change as part of crosscutting content in Earth and space sciences. This is also included in a grade 3 performance expectation in the NGSS (3-LS4-1), but the anatomical and geological evidence expected would be more advanced in NAEP at grade 8. There also is nothing explicit in NAEP that corresponds to the assumption in the NGSS that "natural laws operate today as in the past." *NAEP Content Statement(s):* L08.11, E08.03 *NAEP Science Practice*: Using Scientific Inquiry
Evidence of Common Ancestry and Diversity	MS-LS4-2: Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.	Similar	Both the NGSS and NAEP include the significance of anatomical similarity and differences to infer the degree of relatedness between organisms at grade 8. Both include fossils as an essential piece of evidence, although the NGSS performance expectation is more explicit regarding evolutionary relationships. There is more focus on evolutionary relationships at grade 12 in NAEP. *NAEP Content Statement(s):* L08.11, L08.12 *NAEP Science Practice*: Using Science Principles
Evidence of Common Ancestry and Diversity	MS-LS4-3: Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.	Not Similar	The NGSS include patterns of similarity in embryological development as evidence of relationships between organisms at grade 8. Although NAEP includes anatomical similarity and differences in organisms to infer relatedness, embryological development is not explicitly included in grade 8 or grade 12. *NAEP Content Statement(s):* L08.12 *NAEP Science Practice*: Using Scientific Inquiry
Natural Selection	MS-LS4-4: Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.	Not Similar	Knowledge of natural selection is expected in both the NGSS and NAEP at grade 8. However, the NGSS emphasize the role of genetic variation in a population, which is more consistent with NAEP at grade 12 (L12.13). *NAEP Content Statement(s):* L08.09, L08.11B *NAEP Science Practice*: Using Science Principles

Adaptation	MS-LS4-6: Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.	Similar	Both the NGSS and NAEP include natural selection at grade 8. Both frameworks address the effects of natural selection on traits within a population. *NAEP Content Statement(s):* L08.11 *NAEP Science Practice*: Using Science Principles
NGSS Performance Expectations Not Included in NAEP Science at Grade 8			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Information Processing	MS-LS1-8: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.	NGSS Only	The NGSS include the function of the senses and the role of brain processing at middle school. This topic is not included at any grade level in the NAEP framework. *NAEP Science Practice*: Identifying Science Principles
Inheritance of Traits Variation of Traits	MS-LS3-1: Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.	NGSS Only	Only the NGSS include the possible effects of genetic mutation in middle school. The concept of genetic mutation is included at grade 12 in NAEP (L12.09). *NAEP Science Practice*: Using Science Principles *Cross-grade alignment*: MS-LS3-1 at a higher grade in NAEP
Natural Selection	MS-LS4-5: Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.	NGSS Only	Only the NGSS include the influence of humans on the inheritance of desired traits in organisms at grade 8. Topics such as selective breeding and genetic engineering are more consistent with grade 12 expectations in NAEP. *NAEP Science Practice*: Identifying Science Principles
NAEP Science Content Statements Not Included in the NGSS in Middle School			
Topic: Subtopic	**Content Statement**	**Similarity Rating**	**Summary Statement**
Structures and Functions of Living Systems: Organization and Development	L08.02: Following fertilization, cell division produces a small cluster of cells that then differentiate by appearance and function to form the basic tissues of an embryo.	NAEP Only	Only NAEP includes details on cell differentiation and embryo formation at grade 8. The role of cell differentiation is included in a high school performance expectation in the NGSS (HS-LS1-4). *Cross-grade alignment*: L08.02 at a higher grade in the NGSS

Exhibit E-2c. Content comparison of NGSS performance expectations and NAEP science content statements: Life sciences, high school/grade 12

NGSS Performance Expectations Grouped with NAEP Science Content Statement(s) at Grade 12			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Structure and Function	HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.	Similar	Both the NGSS and NAEP expect that at grade 12, students understand the role of DNA in the production of proteins and the relationship between protein structure and cellular functions. NAEP explicitly includes the concept of amino acid sequencing and the role of proteins in the assembly of fats and carbohydrates. *NAEP Content Statement(s):* L12.02, L12.09A *NAEP Science Practice*: Using Science Principles
Growth and Development of Organisms	HS-LS1-4: Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.	Not Similar	Both the NGSS and NAEP include cellular differentiation in multicellular organisms. However, there is more focus on the role of mitosis in the NGSS (the details of which are excluded in NAEP). Also, NAEP has an emphasis on the regulation of cellular processes by internal and external environments that is not included in the NGSS. *NAEP Content Statement(s):* L12.03 *NAEP Science Practice*: Using Science Principles
Organization for Matter and Energy Flow in Organisms	HS-LS1-5: Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.	Similar	The NGSS and NAEP have similar expectations regarding photosynthesis at grade 12. Both include transformations of matter and energy and the chemical equations for the overall photosynthetic process (but not the specific biochemical steps). *NAEP Content Statement(s):* L12.04A *NAEP Science Practice*: Using Science Principles
Organization for Matter and Energy Flow in Organisms	HS-LS1-6: Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.	Similar	Both the NGSS and NAEP expect students at grade 12 to understand the role of carbon, hydrogen, and oxygen from sugar molecules in the formation of amino acids and other biomolecules essential to living organisms. NAEP also explicitly includes nitrogen and phosphorous as key elements. *NAEP Content Statement(s):* L12.01, L12.04B *NAEP Science Practice*: Using Science Principles

Organization for Matter and Energy Flow in Organisms	HS-LS1-7: Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.	Not Similar	The NGSS emphasize the chemical process of cellular respiration and the resulting energy transfer at grade 12. This topic is subsumed within a broader NAEP content statement on matter and energy transformations in living systems. There is no equivalent content statement in NAEP related to cellular respiration at the same level of detail as in this NGSS performance expectation, so this topic may receive less emphasis in NAEP. *NAEP Content Statement(s):* L12.06 *NAEP Science Practice*: Using Science Principles
Interdependent Relationships in Ecosystems	HS-LS2-1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.	Not Similar	The NGSS emphasize factors that affect the "carrying capacity" of ecosystems, while NAEP is more broadly focused on how environmental change can affect the interrelationships and interdependence of organisms in ecosystems at grade 12. The effect of the availability of biotic and abiotic resources on the size of populations that can be supported in an ecosystem is included at grade 8 in NAEP (L08.07). *NAEP Content Statement(s):* L12.07 *NAEP Science Practice*: Using Science Principles *Cross-grade alignment*: HS-LS2-1 at a lower grade in NAEP
Interdependent Relationships in Ecosystems Ecosystem Dynamics, Functioning, and Resilience	HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.	Similar	Both the NGSS and NAEP expect students at grade 12 to understand the interdependence of organisms in an ecosystem and how changes to that ecosystem affect populations and biodiversity. *NAEP Content Statement(s):* L12.07 *NAEP Science Practice*: Using Scientific Inquiry
Cycles of Matter and Energy Transfer in Ecosystems	HS-LS2-3: Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.	Not Similar	Although both the NGSS and NAEP include the cycling of matter and flow of energy in ecosystems, only the NGSS emphasize the role of aerobic and anaerobic respiration in different environments. There is no expectation in NAEP regarding aerobic versus anaerobic conditions. *NAEP Content Statement(s):* L12.06 *NAEP Science Practice*: Using Science Principles

Cycles of Matter and Energy Transfer in Ecosystems	HS-LS2-4: Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.	Similar	Both the NGSS and NAEP expect grade 12 students to trace matter and energy through the tropic levels of an ecosystem, understanding that both matter and energy are always conserved. NAEP also explicitly includes nonliving parts of ecosystems in the cycling of matter and energy. *NAEP Content Statement(s):* L12.05, L12.06 *NAEP Science Practice*: Using Science Principles
Cycles of Matter and Energy Transfer in Ecosystems Energy in Chemical Processes	HS-LS2-5: Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.	Not Similar	Both the NGSS and NAEP include the role of photosynthesis and cellular respiration in the cycling of carbon through ecosystems. The NGSS emphasize the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere in life sciences. The movement of elements, including carbon, between the lithosphere, atmosphere, hydrosphere, and biosphere is included under biogeochemical cycles in Earth and space sciences (E12.11, E12.12). The NAEP content statements in Earth and space sciences are less focused on photosynthesis and cellular respiration than the NGSS life science performance expectation. *NAEP Content Statement(s):* L12.04, L12.06, E12.11 *NAEP Science Practice*: Using Science Principles
Ecosystem Dynamics, Functioning, and Resilience	HS-LS2-6: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.	Similar	Both the NGSS and NAEP emphasize complex interactions in ecosystems that maintain stability and the impact of natural or human-made disturbances that result in changes in ecosystems. *NAEP Content Statement(s):* L12.07 *NAEP Science Practice*: Using Science Principles
Ecosystem Dynamics, Functioning, and Resilience Biodiversity and Humans	HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.	Not Similar	Both the NGSS and NAEP include human impact on the environment, but there are differences in focus. The NGSS performance expectation focuses on ways that humans can minimize their impact on the environment, while NAEP emphasizes environmental changes (natural and human-caused) that impact other species. The NGSS emphasize sustaining biodiversity, which is not an explicit focus in NAEP at grade 12. A related content statement is included in biogeochemical cycles in Earth and space sciences at grade 8 in NAEP (E08.15). *NAEP Content Statement(s):* L12.07 *NAEP Science Practice*: Using Technological Design *Cross-grade alignment:* HS-LS2-7 at a lower grade in NAEP

Structure and Function Inheritance of Traits	HS-LS3-1: Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.	Similar	Both the NGSS and NAEP expect students at grade 12 to understand that DNA is the heritable genetic material and codes for traits seen in offspring. The two frameworks expect a similar level of understanding of genetic concepts. The NAEP content statements are more explicit with respect to the role of genes than the NGSS performance expectation, but the role of both genes and chromosomes is included in the underlying disciplinary core idea. *NAEP Content Statement(s):* L12.08, L12.09A *NAEP Science Practice*: Identifying Science Principles
Variation of Traits	HS-LS3-2: Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.	Not Similar	Both the NGSS and NAEP include recombination and mutation as sources of genetic variation at grade 12. However, there is a difference in focus. The NGSS emphasize how genetic variations occur, while NAEP focuses on the consequences of changes to the DNA for offspring. A more comparable NGSS performance expectation is found at grade 8 (MS-LS3-1), which includes that mutations may affect proteins and result in harmful, helpful or neutral effects to organisms. Also, replication errors included in the NGSS at grade 12 is not explicitly stated in NAEP. *NAEP Content Statement(s):* L12.09, L12.10, L12.13A *NAEP Science Practice*: Using Science Principles *Cross-grade alignment*: L12.09 at a lower grade in the NGSS
Variation of Traits	HS-LS3-3: Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.	Similar	Both the NGSS and NAEP include natural selection and evolution as models to explain the variation and distribution of traits in a population at grade 12. The NGSS emphasize the use of mathematics to describe the probability of traits in response to both genetic and environmental factors. This emphasis is not explicit in NAEP. *NAEP Content Statement(s):* L12.13 *NAEP Science Practice*: Using Science Principles
Evidence of Common Ancestry and Diversity	HS-LS4-1: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.	Similar	Both the NGSS and NAEP include lines of evidence for common ancestry and biological evolution (e.g., molecular and anatomical similarity, DNA sequencing, and the fossil record). The NGSS also explicitly include the order of appearance of structures in embryological development, which is not stated in NAEP. *NAEP Content Statement(s):* L12.11, L12.12 *NAEP Science Practice*: Identifying Science Principles

Natural Selection Adaptation	HS-LS4-2: Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.	Similar	Both the NGSS and NAEP expect grade 12 students to demonstrate understanding of the evolutionary process, considering the influence of the four factors stated in the NGSS performance expectation. *NAEP Content Statement(s):* L12.13 *NAEP Science Practice*: Using Science Principles
Natural Selection Adaptation	HS-LS4-3: Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.	Similar	The NGSS and NAEP include explanations of the distribution of traits in organisms based on natural selection at grade 12. The NGSS emphasize analyzing shifts in numerical distribution of traits as evidence to support explanations. NAEP also includes using graphs or tables showing distributions of traits, but there is not the same focus on the application of statistics and probability as in the NGSS. *NAEP Content Statement(s):* L12.11, L12.13 *NAEP Science Practice*: Using Science Principles
Adaptation	HS-LS4-4: Construct an explanation based on evidence for how natural selection leads to adaptation of populations.	Similar	Both the NGSS and NAEP expect grade 12 students to understand how natural selection leads to adaptation of populations. The NGSS emphasize using data to provide evidence for how specific biotic and abiotic differences contribute to a change in gene frequency over time. NAEP includes examples of modern diversity and evolutionary changes in populations. *NAEP Content Statement(s):* L12.11, L12.13 *NAEP Science Practice*: Using Science Principles
Adaptation	HS-LS4-5: Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.	Similar	The NGSS and NAEP include how changes in environmental conditions may result in changes in the populations of organisms and species over time. The NGSS explicitly include evolution of new species and extinction of others. This is not explicitly stated in NAEP at grade 12, but may be subsumed under the broader understandings related to the history of life on Earth. Extinction is also included in NAEP at grade 8 (L08.11). *NAEP Content Statement(s):* L12.07, L12.13 *NAEP Science Practice*: Using Scientific Inquiry

Adaptation Biodiversity and Humans	HS-LS4-6: Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.	Not Similar	The NGSS emphasize the mitigation of adverse impacts of human activity on biodiversity. Although NAEP includes the impact of humans on other species, the grade 12 content statements are not focused on sustaining biodiversity. *NAEP Content Statement(s):* L12.07B *NAEP Science Practice*: Using Technological Design
NGSS Performance Expectations Not Included in NAEP Science at Grade 12			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Structure and Function	HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.	NGSS Only	The NGSS include the hierarchical organization of interacting systems within multicellular organisms at grade 12. Organs and organ systems are included at grade 8 in NAEP, but at a lower level than is expected in this NGSS performance expectation. *NAEP Science Practice*: Using Science Principles
Structure and Function	HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.	NGSS Only	The NGSS explicitly include the concept of feedback mechanisms and homeostasis at grade 12. This concept is not the focus in a NAEP content statement at any grade level. *NAEP Science Practice*: Using Scientific Inquiry
Social Interactions and Group Behavior	HS-LS2-8: Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.	NGSS Only	Only the NGSS explicitly include the role of group behavior and social interactions on the survival of species. This topic is not included in NAEP at any grade level. *NAEP Science Practice*: Using Scientific Inquiry
NAEP Science Content Statements Not Included in the NGSS in High School			
Topic: Subtopic	**Content Statement**	**Similarity Rating**	**Summary Statement**
None			

Exhibit E-3a. Content comparison of NGSS performance expectations and NAEP science content statements: Earth and space sciences, grade 4

NGSS Performance Expectations Grouped with NAEP Science Content Statement(s) at Grade 4			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
The History of Planet Earth	4-ESS1-1: Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.	Not Similar	Both the NGSS and NAEP include changes in Earth's surface at grade 4, but the focus and level of expectations is quite different. The NGSS emphasize explanations for changes over time, while NAEP includes knowledge of changes due to both slow processes (e.g., erosion, weathering, and soil deposition) and rapid processes (e.g., landslides, volcanic eruptions, and earthquakes). The emphasis in NAEP at grade 4 is on changes that take place within a human lifespan and is more consistent with the performance expectation at grade 2 in the NGSS (2-ESS1-1). The NGSS performance expectation at grade 4 includes patterns of rock formations and fossils; this content is not included in NAEP until grade 8 (E08.04). *NAEP Content Statement(s):* E04.03 *NAEP Science Practice*: Using Scientific Inquiry *Cross-grade alignment*: 4-ESS1-1 at a higher grade in NAEP
Earth Materials and Systems Biogeology	4-ESS2-1: Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.	Similar	Both the NGSS and NAEP include the effects of weathering and erosion on Earth's surface. Both include erosion by water, ice, and wind. The NGSS also include erosion by vegetation, which is not explicitly included in NAEP. Both the NGSS and NAEP consider factors affecting erosion such as angle of slopes and level of vegetation in the downhill movement of water, speed of wind, and the freeze/thaw cycle. NAEP also considers other types of changes in Earth materials, such as rust on metals and wood rot on buildings, that are not included in the NGSS. *NAEP Content Statement(s):* E04.03 *NAEP Science Practice*: Using Scientific Inquiry

Natural Resources	4-ESS3-1: Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.	Similar	Both the NGSS and NAEP include human use of natural resources and their impact on the environment. Both include renewable versus non-renewable resources, and NAEP also explicitly includes recycling and reuse. The NGSS focus on energy and fuel, while NAEP is broader, including other types of limited resources such as metals, fresh water, and farmland. NAEP also explicitly includes the beneficial effects of humans on the environment, which is not explicitly included at grade 4 in the NGSS. This aspect of the NAEP content statements is more consistent with a NGSS performance expectation at grade 5 (5-ESS3-1). *NAEP Content Statement(s):* E04.10, E04.11 *NAEP Science Practice*: Using Science Principles
Natural Hazards	4-ESS3-2: Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.	Not Similar	Although both the NGSS and NAEP include understanding that humans are dependent on the natural environment at grade 4, only the NGSS explicitly include solutions to reduce the impacts of natural Earth processes (e.g., earthquakes, floods, tsunamis, and volcanic eruptions). In contrast, NAEP focuses on human impacts on the environment (beneficial or detrimental). *NAEP Content Statement(s):* E04.11 *NAEP Science Practice*: Using Technological Design

NGSS Performance Expectations Not Included in NAEP Science at Grade 4			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Plate Tectonics and Large-Scale System Interactions	4-ESS2-2: Analyze and interpret data from maps to describe patterns of Earth's features.	NGSS Only	Only the NGSS include interpreting data from maps to describe patterns in Earth's features at grade 4. Use of topographic maps is not expected until grade 8 in NAEP. *NAEP Science Practice*: Using Scientific Inquiry
NAEP Science Content Statements Not Included in the NGSS at Grade 4			
Topic: Subtopic	**Content Statement**	**Similarity Rating**	**Summary Statement**
Earth in Space and Time: Objects in the Universe	E04.01: Objects in the sky have patterns of movement. The Sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The Moon appears to move across the sky on a daily basis much like the Sun.	NAEP Only	NAEP includes daily and seasonal patterns in the apparent movement of objects in the sky (Sun and moon) at grade 4. Daily patterns in the movements of the Sun and moon are included at grade 1 in the NGSS (1-ESS1-1). The appearance of the stars is also included in the NGSS at grade 1, but is not explicitly included in NAEP. The change in the Sun's path over the seasons included at grade 4 in NAEP is related to content at grade 5 in the NGSS (5-ESS1-2). *Cross-grade alignment*: E04.01 at a lower grade in the NGSS
Earth in Space and Time: Objects in the Universe	E04.02: The observable shape of the Moon changes from day to day in a cycle that lasts about a month.	NAEP Only	NAEP includes daily changes in the observable shape (phases) of the moon over its monthly cycle at grade 4. A performance expectation in the NGSS at grade 1 (1-ESS1-1) includes daily patterns of movement of the moon, but the moon's phases and monthly cycle are not explicitly included in the NGSS until middle school (MS-ESS1-1). At that level, explanations based on a model of the solar system are expected, which is beyond the basic observations of patterns at grade 4 in NAEP. *Cross-grade alignment*: E04.02 at a lower grade in the NGSS
Earth Structures: Properties of Earth Materials	E04.04: Earth materials that occur in nature include rocks, minerals, soils, water, and the gases of the atmosphere.	NAEP Only	NAEP includes knowledge of Earth materials (such as rocks, minerals, soils, water, and the gases of the atmosphere) at grade 4. Basic knowledge of Earth materials is not a focus in NGSS, although a performance expectation at grade 2 (2-ESS2-3) includes identifying where water is found on Earth (ocean, rivers, lakes, and ponds). The NRC K-12 framework includes rocks, soils, sand, and water in the K-2 grade band, although there is not an NGSS performance expectation that emphasizes this.

Earth Structures: Properties of Earth Materials	E04.05: Natural materials have different properties that sustain plant and animal life.	NAEP Only	NAEP includes knowledge of the properties of natural materials that sustain plant and animal life (e.g., air, water, minerals, soil, shelter, and sunlight) in Earth and space sciences at grade 4. Related content about the needs of plants and animals for survival is included in the NGSS at the kindergarten level (K-ESS3-1), although the focus on the properties of natural materials is not the same as the NAEP grade 4 content statement. The NRC K-12 framework includes Earth's resources needed by living things in the K-2 grade band. *Cross-grade alignment*: E04.05 at a lower grade in the NGSS
Earth Structures: Properties of Earth Materials	E04.06: Some Earth materials have properties either in their present form or after design and modification that make them useful in solving human problems and enhancing the quality of life, as in the case of materials used for building or fuels used for heating and transportation.	NAEP Only	NAEP includes properties of natural materials that make them useful for humans (natural or modified), which includes knowledge of natural versus man-made materials, at grade 4 Earth and space sciences. An NGSS performance expectation at grade 8 in physical science (MS-PS1-3) includes the formation of synthetic materials from natural resources, but is focused on chemical processes. The basic knowledge of properties of materials included at grade 4 in NAEP is not a focus in the NGSS.
Earth Systems: Energy in Earth Systems	E04.07: The Sun warms the land, air, and water and helps plants grow.	NAEP Only	NAEP includes knowledge that the Sun provides energy to warm the land, air, and water and to help plants grow at grade 4 in Earth and space sciences. This is crosscutting content that is also included in physical science (P04.08) and life science (L04.02) in NAEP. Related content is included in the NGSS across multiple performance expectations in grades K-2 (K-PS3-1, K-LS1-1, 2-LS2-1). *Cross-grade alignment*: E04.07 at a lower grade in the NGSS
Earth Systems: Climate and Weather	E04.08: Weather changes from day to day and during the seasons.	NAEP Only	NAEP includes knowledge that weather changes from day to day and during the seasons at grade 4. Related content is included in the NGSS performance expectations in kindergarten (K-ESS2-1) and grade 3 (3-ESS2-1). *Cross-grade alignment*: E04.08 at a lower grade in the NGSS
Earth Systems: Climate and Weather	E04.09: Scientists use tools for observing, recording, and predicting weather changes from day to day and during the seasons.	NAEP Only	NAEP includes tools for observing, recording, and predicting weather changes at grade 4. Related content is included in the NGSS performance expectations in kindergarten (K-ESS2-1) and grade 3 (3-ESS2-1). *Cross-grade alignment*: E04.09 at a lower grade in the NGSS

Exhibit E-3b. Content comparison of NGSS performance expectations and NAEP science content statements: Earth and space sciences, middle school/grade 8

NGSS Performance Expectations Grouped with NAEP Science Content Statement(s) at Grade 8			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
The Universe and Its Stars Earth and the Solar System	MS-ESS1-1: Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.	Similar	Both the NGSS and NAEP emphasize using a model of the solar system to describe and explain cyclic patterns of lunar phases, eclipses of the Sun and moon, and seasons at grade 8. This includes understanding the effect of the tilt of Earth's axis of rotation relative to the plane of its orbit around the Sun. NAEP also includes explanations of other phenomena, such as day and night and the year, which are not explicit in the NGSS performance expectation. *NAEP Content Statement(s):* E08.02B. E08.12 *NAEP Science Practice*: Using Science Principles
The Universe and Its Stars Earth and the Solar System	MS-ESS1-2: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.	Similar	Both the NGSS and NAEP emphasize the role of gravity as the force that keeps objects in the solar system in motion at grade 8. The NGSS also include motions within galaxies, but this aspect of the performance expectation is not included in NAEP at grade 8. Galaxies are included at grade 12 in NAEP. *NAEP Content Statement(s):* E08.02 *NAEP Science Practice*: Using Science Principles
Earth and the Solar System	MS-ESS1-3: Analyze and interpret data to determine scale properties of objects in the solar system.	Not Similar	The NGSS include analyzing and interpreting data to determine scale properties of objects in the solar system. At grade 8, NAEP includes knowledge of the structure and objects of the solar system (e.g., Sun, planets, moons, asteroids, and comets), but does not have a focus on scale properties. Although knowledge of scale properties may not be expected, data interpretation regarding scale properties might be included in NAEP through the practice of Using Scientific Inquiry. *NAEP Content Statement(s):* E08.01 *NAEP Science Practice*: Using Scientific Inquiry

The History of Planet Earth	MS-ESS1-4: Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.	Similar	Both the NGSS and NAEP include using evidence from rock strata and the fossils they contain to measure geologic time and describe Earth's history. The NGSS emphasize relative ages of major geologic events and changes in life forms. NAEP also focuses on fossils providing evidence of how life and environmental conditions have changed in a given location, which is included at grade 3 in the NGSS (3-LS4-1). *NAEP Content Statement(s):* E08.03, E08.04 *NAEP Science Practice*: Using Science Principles
Earth's Materials and Systems	MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.	Not Similar	The NGSS include developing a model for the cycling of Earth's materials and flow of energy that emphasizes the rock cycle (melting, crystallization, weathering, deformation, and sedimentation) at grade 8. NAEP is more focused on the evidence found in existing rocks and rock formations of the materials, conditions, and forces that created them. *NAEP Content Statement(s):* E08.05 *NAEP Science Practice*: Using Science Principles
Earth's Materials and Systems The Roles of Water in Earth's Surface Processes	MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.	Similar	Both the NGSS and NAEP include geological processes resulting from lithospheric plate movement that have changed Earth's surface (e.g., mountain building, earthquakes, and volcanic eruptions) as well as surface effects, such as weathering, erosion, and deposition. Both the NGSS and NAEP include changes that occur at varying time and spatial scales. *NAEP Content Statement(s):* E08.04, E08.09 *NAEP Science Practice*: Using Science Principles
The History of Planet Earth Plate Tectonics and Large-Scale System Interactions	MS-ESS2-3: Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.	Similar	Both the NGSS and NAEP include evidence of tectonic plate movement at grade 8. Both focus on evidence such as the distribution of fossils, continental shapes, and locations of ocean structures (such as ridges, fracture zones, and trenches). *NAEP Content Statement(s):* E08.03, E08.04, E08.09 *NAEP Science Practice*: Using Scientific Inquiry

The Roles of Water in Earth's Surface Processes	MS-ESS2-4: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.	Not Similar	Both the NGSS and NAEP include a model of Earth's water cycle at grade 8, but there are differences in emphasis. The NGSS emphasize the role of energy and gravity as water changes state and moves through the multiple pathways of the hydrologic cycle. NAEP focuses on the circulation of water through the crust, oceans and atmosphere, and the changes of state (evaporation, condensation, and precipitation). NAEP includes the Sun as the source of energy, but does not explicitly include the role of gravity. NAEP also includes that water covers the majority of Earth's surface, which is not included in the NGSS performance expectation. *NAEP Content Statement(s):* E08.11, E08.14 *NAEP Science Practice*: Using Science Principles
The Roles of Water in Earth's Surface Processes Weather and Climate	MS-ESS2-5: Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.	Similar	Both the NGSS and NAEP emphasize complex patterns of atmospheric movement and how air masses flowing from regions of high pressure to low pressure influence weather. Both include the interpretation of weather maps and diagrams or images of weather systems. NAEP explicitly includes global patterns of atmospheric movement and the effect of oceans on climate. The NGSS also emphasize how weather can be predicted within probabilistic ranges. *NAEP Content Statement(s):* E08.13A *NAEP Science Practice*: Using Scientific Inquiry
The Roles of Water in Earth's Surface Processes Weather and Climate	MS-ESS2-6: Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.	Similar	Both the NGSS and NAEP emphasize using a model to explain how uneven heating by the Sun and Earth's rotation drives convection within the atmosphere and oceans. Both consider effects on regional climates as a function of latitude, ocean currents, and global wind patterns. The Coriolis effect is included in the NGSS at grade 8. This specific portion of the NGSS performance expectation is explicitly excluded at grade 8, but included at grade 12, in NAEP. *NAEP Content Statement(s):* E08.11, E08.12, E08.13 *NAEP Science Practice*: Using Science Principles

Natural Hazards	MS-ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.	Not Similar	The NGSS include interpreting data on natural hazards to forecast future events and inform the development of technologies to mitigate their effects. This includes knowledge that some natural hazards (e.g., volcanic eruptions and severe weather) allow for reliable predictions, while others (e.g., earthquakes, tsunamis) are not currently predictable. Although NAEP includes knowledge about natural hazards (such as earthquakes, volcanic eruptions, and weather), it does not focus on forecasting future events at grade 8. Weather prediction is included at a very low level at grade 4 in NAEP (E04.09). *NAEP Content Statement(s):* E08.09, E08.13 *NAEP Science Practice*: Using Technological Design
Human Impacts on Earth Systems	MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	Similar	Both the NGSS and NAEP emphasize human impacts on the environment at grade 8. This includes a wide range of effects due to human activities, such as water usage, land usage, consumption of energy resources, and pollution of air, water, and land. These effects consider both the impact on the physical environment and the impact on other species. The NGSS performance expectation involves applying science principles to design a method for monitoring and minimizing human impact. Although not explicitly stated in the content statement, NAEP includes both positive and negative impacts, so this might be included in NAEP through the practice of Using Technological Design. *NAEP Content Statement(s):* E08.15 *NAEP Science Practice*: Using Technological Design
Human Impacts on Earth Systems	MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.	Not Similar	The NGSS include how increases in human population and per capita consumption of natural resources impact Earth's systems at grade 8. NAEP includes, generally, the impact of human activities on the environment in Earth and space sciences (E08.15) and how the availability of natural resources affects the populations that an ecosystem can support in life science (L08.07). However, consideration of the impact of human population growth and per capita consumption of natural resources in not a focus in NAEP at any grade. *NAEP Content Statement(s):* E08.15, L08.07 *NAEP Science Practice*: Using Scientific Inquiry

Global Climate Change	MS-ESS3-5: Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.	Not Similar	The NGSS emphasize evidence of factors that contribute to global warming, including both human activities (e.g., fossil fuel consumption and agricultural activity) and natural processes (e.g., changes in incoming solar radiation or volcanic activity). NAEP includes the impact of human activities on the environment, which includes global warming. Natural processes that contribute to global warming are not a focus in NAEP at grade 8; there is some consideration of this at grade 12. *NAEP Content Statement(s):* E08.15 *NAEP Science Practice*: Using Scientific Inquiry

NGSS Performance Expectations Not Included in NAEP Science at Grade 8			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Natural Resources	MS-ESS3-1: Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.	NGSS Only	Only the NGSS include concepts related to how the uneven distributions of Earth's resources (mineral, energy, and groundwater) are the result of past and current geoscience processes. Although NAEP includes geological processes that have changed Earth's surface over time, it does not focus on the distribution of resources. *NAEP Science Practice*: Using Science Principles
NAEP Science Content Statements Not Included in the NGSS in Middle School			
Topic: Subtopic	**Content Statement**	**Similarity Rating**	**Summary Statement**
Earth Structures: Properties of Earth Materials	E08.06: Soil consists of weathered rocks and decomposed organic material from dead plants, animals, and bacteria. Soils are often found in layers with each having a different chemical composition and texture.	NAEP Only	Only NAEP includes knowledge of the composition of soil at grade 8. This content is not included in the NGSS at any grade level.
Earth Structures: Properties of Earth Materials	E08.07: The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor. The atmosphere has a different physical and chemical composition at different elevations.	NAEP Only	Only NAEP includes knowledge of the composition of the atmosphere at grade 8. This content is not included in the NGSS at any grade level.
Earth Structures: Tectonics	E08.08: Earth is layered with a lithosphere; a hot, convecting mantle; and a dense, metallic core.	NAEP Only	Only NAEP includes knowledge of the structure and composition of Earth's layers (lithosphere, mantle, and core) at grade 8. The NGSS include a model of Earth's interior at grade 12 (HS-ESS2-3), but at a more advanced level than the expectations at grade 8 in NAEP. *Cross-grade alignment*: E08.08 at a higher grade in the NGSS
Earth Structures: Tectonics	E08.10: Earth as a whole has a magnetic field that is detectable at the surface with a compass. Earth's magnetic field is similar to the field of a natural or manmade magnet with north and south poles and lines of force. For thousands of years, people have used compasses to aid in navigation on land and sea.	NAEP Only	Only NAEP includes knowledge of Earth's magnetic field and its effects at grade 8. An NGSS performance expectation in physical sciences at grade 8 (MS-PS2-5) includes the concept of magnetic fields as it relates to forces acting at a distance, but does not include Earth's magnetic field. Knowledge of Earth's magnetic field is included in a grade 12 NGSS performance expectation (HS-ESS2-3) based on a model of Earth's interior. *Cross-grade alignment*: E08.10 at a higher grade in the NGSS

Exhibit E-3c. Content comparison of NGSS performance expectations and NAEP science content statements: Earth and space sciences, high school/grade 12

NGSS Performance Expectations Grouped with NAEP Science Content Statement(s) at Grade 12			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
The Universe and Its Stars Energy in Chemical Processes and Everyday Life	HS-ESS1-1: Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.	Similar	Both the NGSS and NAEP include the concept that the Sun is the largest external source of energy for Earth and that fusion is the nuclear process that provides this energy. Both include the fusion of hydrogen to form helium in stars in Earth and space sciences. Additional details of nuclear processes are included in both NAEP and the NGSS in physical sciences at grade 12. The NGSS also include a model of the life span of the sun. *NAEP Content Statement(s):* E12.03A, E12.09A *NAEP Science Practice*: Using Science Principles
The Universe and Its Stars Electromagnetic Radiation	HS-ESS1-2: Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.	Similar	Both the NGSS and NAEP include evidence of the Big Bang theory, focusing on red shifting, and spectroscopy to determine the composition of stars. The NGSS also include the cosmic microwave background as evidence of the Big Bang, but this is not explicitly mentioned in NAEP. *NAEP Content Statement(s):* E12.01, E12.02 *NAEP Science Practice*: Using Science Principles
The Universe and Its Stars	HS-ESS1-3: Communicate scientific ideas about the way stars, over their life cycle, produce elements.	Similar	Both the NGSS and NAEP include knowledge of how nuclear processes in stars produce elements heavier than helium and hydrogen, but both exclude details of the different nuclear reaction pathways. The NGSS include additional knowledge that the generation of these heavier elements is dependent on the mass of the star and the stage of its lifetime. This is not explicit in NAEP. *NAEP Content Statement(s):* E12.03 *NAEP Science Practice*: Using Science Principles
Earth and the Solar System	HS-ESS1-4: Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.	Not Similar	The NGSS include mathematical models to predict the motion of objects in the solar system based on Newtonian gravitational laws. NAEP includes understanding of the universal force of gravitation in physical science, but does not have the same focus as the NGSS in Earth and space sciences on predicting the motion of objects in the solar system. NAEP includes basic knowledge of the role of gravity in the solar system at grade 8, but not the application of Newton's gravitational laws. *NAEP Content Statement(s):* P12.22 *NAEP Science Practice*: Using Science Principles

The History of Planet Earth Plate Tectonics and Large-Scale System Interactions Nuclear Processes	HS-ESS1-5: Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.	Similar	Both the NGSS and NAEP include knowledge that the ages of crustal rocks can be determined using the theory of plate tectonics. Both include sea floor spreading and subduction as evidence to support this theory and evidence for rock dating from radioactive isotopes. *NAEP Content Statement(s):* E12.04, E12.08 *NAEP Science Practice*: Using Scientific Inquiry
The History of Planet Earth Nuclear Processes	HS-ESS1-6: Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.	Similar	Both the NGSS and NAEP include theories of planet formation and various forms of evidence (e.g., radioactive dating of meteorites, Earth materials, and moon rocks) to support conclusions about the age of Earth's solar system (4.6 billion years). The NGSS also include analysis of the size and composition of other objects in the solar system and crater impact records. These are not explicitly stated in NAEP. *NAEP Content Statement(s):* E12.05 *NAEP Science Practice*: Using Science Principles
Earth Materials and Systems Plate Tectonics and Large-Scale System Interactions	HS-ESS2-1: Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.	Similar	Both the NGSS and NAEP include knowledge of the various internal and external processes that contribute to the formation of Earth features. Both include knowledge that the various processes can occur gradually over hundreds of millions of years (e.g., mountain building) or sporadically (e.g., volcanic eruption). They also include knowledge of both continental and ocean-floor features. *NAEP Content Statement(s):* E12.07, E12.08 *NAEP Science Practice*: Using Science Principles
Earth Materials and Systems Weather and Climate	HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.	Not Similar	The NGSS emphasize changes in Earth's surface that create feedbacks that cause changes to other Earth systems. NAEP includes content statements focused on systems that influence climate and the effect of natural systems on humans, but does not have the same level of emphasis on the interaction of Earth systems in general. *NAEP Content Statement(s):* E12.10, E12.13 *NAEP Science Practice*: Using Scientific Inquiry

Earth Materials and Systems Plate Tectonics and Large-Scale System Interactions Wave Properties	HS-ESS2-3: Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	Not Similar	Both the NGSS and NAEP include a model of Earth's interior and the role of convection currents in phenomena such as plate tectonics, but there are some differences in focus. NAEP includes content statements covering plate tectonic theory and the role of Earth's internal source of energy in the movement of matter through Earth's systems. In contrast, this NGSS performance expectation emphasizes analysis of different types of evidence for Earth's internal structure. *NAEP Content Statement(s):* E12.08, E12.09, E12.12A *NAEP Science Practice*: Using Science Principles
Earth and the Solar System Earth Materials and Systems Weather and Climate	HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	Similar	Both the NGSS and NAEP include understanding that climate change is a result of variations in energy input and output in Earth systems. The NGSS include various causes of climate change on different time scales. NAEP also considers the impact of static conditions (e.g., positions of mountains and oceans) on climate. *NAEP Content Statement(s):* E12.10 *NAEP Science Practice*: Using Science Principles
The Roles of Water in Earth's Surface Processes	HS-ESS2-5: Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.	Not Similar	Although both the NGSS and NAEP include understandings related to the movement of materials through Earth systems and physical processes involving water (e.g., erosion, weathering, and acid rain), the emphasis is different. The NGSS focus on the properties of water and its effects on Earth materials and surfaces. NAEP more broadly covers biogeochemical cycles in Earth and space sciences. Special properties of water are addressed in NAEP in physical science (P12.05). *NAEP Content Statement(s):* E12.11, E12.13 *NAEP Science Practice*: Using Scientific Inquiry
Weather and Climate	HS-ESS2-6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	Similar	Both the NGSS and NAEP include developing a model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. The NGSS emphasize a quantitative model, but this is not explicitly described in NAEP. *NAEP Content Statement(s):* E12.11, E12.12 *NAEP Science Practice*: Using Science Principles

Weather and Climate Biogeology	HS-ESS2-7: Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.	Not Similar	Both the NGSS and NAEP include concepts related to the coevolution of Earth's systems and life on Earth, but the focus and level of expectations differ. While NAEP includes evidence for life forms throughout Earth's history and the impact of life on the Earth's atmosphere, the NGSS performance expectation is broader. *NAEP Content Statement(s):* E12.06 *NAEP Science Practice*: Using Science Principles
Natural Resources Natural Hazards	HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.	Not Similar	Both the NGSS and NAEP include the interaction of humans and natural systems, but the focus is different. The NGSS emphasize a range of factors affecting human activity, including natural resources, natural hazards and other geological events, and climate change. NAEP emphasizes human dependence on processes in natural ecosystems; the effects of natural hazards and climate change in the NGSS performance expectation are not explicitly included. *NAEP Content Statement(s):* E12.13 *NAEP Science Practice*: Using Science Principles
Human Impacts on Earth Systems	HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.	Not Similar	The NGSS emphasize technological solutions that reduce impacts of human activities on natural systems at grade 12. This performance expectation in the NGSS is more closely aligned with grade 8 in the NAEP framework (E08.15). Although NAEP may include some human impact items at grade 12, the emphasis is more on how natural systems provide processes that affect humans and support human life (e.g., maintaining quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of plant and animal wastes, and recycling of nutrients). *NAEP Content Statement(s):* L12.07 *NAEP Science Practice*: Using Technological Design *Cross-grade alignment*: HS-ESS3-4 at a lower grade in NAEP

Global Climate Change	HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.	Not Similar	Both the NGSS and NAEP include systems that influence climate at grade 12, but the focus is different. The NGSS emphasize using climate models to predict global or regional climate change (e.g., temperature and precipitation) and future impacts on Earth systems (e.g., sea level, glacial ice volumes, and composition of the atmosphere and oceans). NAEP, more generally, focuses on how climate is determined by energy from the Sun and factors such as cloud cover, atmospheric gases, Earth's rotation, and topographical feature (e.g., mountain ranges and oceans, seas, and lakes). NAEP also considers the effects of atmospheric conditions on climate, but this does not have the same focus as in the NGSS at grade 12. NAEP has more focus on the causes and effects of global warming at grade 8 (E08.15). *NAEP Content Statement(s):* E12.10, E12.13 *NAEP Science Practice*: Using Scientific Inquiry
Global Climate Change Weather and Climate	HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	Not Similar	Both the NGSS and NAEP include relationships among Earth systems (lithosphere, atmosphere, hydrosphere, and biosphere) at grade 12, but the focus is different. The focus in the NGSS is on how relationships in natural systems are being modified by humans. NAEP focuses on the cycling of elements among Earth systems and how natural ecosystems affect humans. There is less focus on the impact of human activity at grade 12 in NAEP. Human impact has a greater focus at grade 8 in NAEP (E08.15), but the expectations related to relationships among Earth systems are not at the level included at grade 12 in the NGSS. *NAEP Content Statement(s):* E12.13, E12.11 *NAEP Science Practice*: Using Science Principles

NGSS Performance Expectations Not Included in NAEP Science at Grade12			
Disciplinary Core Idea	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Natural Resources	HS-ESS3-2: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.	NGSS Only	Only the NGSS include the consideration of cost-benefit ratios in evaluating design solutions for developing, managing, and utilizing energy and mineral resources. While NAEP includes human use of natural resources, economic considerations are not part of the NAEP science framework. *NAEP Science Practice*: Using Technological Design
Human Impacts on Earth Systems	HS-ESS3-3: Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.	NGSS Only	Only the NGSS include the relationship among the management of natural resources, the sustainability of human populations, and biodiversity. *NAEP Science Practice*: Using Science Principles
NAEP Science Content Statements Not Included in the NGSS in High School			
Topic: Subtopic	**Content Statement**	**Similarity Rating**	**Summary Statement**
None			

Appendix F: Content Comparison of NGSS Performance Expectations in Engineering, Technology, and Applications of Science (ETS) and NAEP TEL Assessment Targets

Appendix F includes detailed content comparisons of NGSS performance expectations in engineering, technology, and applications of science (ETS) and NAEP TEL assessment targets. There are three exhibits, one for each grade level:

Exhibit F-1: Grades 3-5/Grade 4

Exhibit F-2: Middle School/Grade 8

Exhibit F-3: High School/Grade 12

These exhibits present the NGSS performance expectations in ETS (and disciplinary core ideas from the NRC K-12 framework on which they are based) and list the NAEP TEL assessment targets with which they were compared. Content groupings are presented for the two different types of NGSS performance expectations in ETS: engineering design and those in the sciences with connections to the ETS disciplinary core ideas. The exhibits provide similarity ratings for each content grouping and summary statements with descriptive information about the areas of similarity and dissimilarity between the NGSS and NAEP TEL at the corresponding grade level. These summary statements are based on discussions during the expert panel meeting; information provided in the NGSS (descriptions of performance expectations, clarification statements, assessment boundaries, and elements of the underlying disciplinary core ideas from the NRC K-12 framework); and information in the NAEP TEL framework. In addition, science similarity ratings were also included for the NGSS performance expectations with connections to ETS, which were also compared with the NAEP science framework (as described in Appendix E).

There are four main sections in each exhibit:

(1) **NGSS engineering design performance expectations grouped with NAEP TEL assessment targets at the corresponding grade level**. This is the first section at the top of each exhibit. It presents the NGSS performance expectations in engineering, technology, and applications of science (ETS) that were grouped with NAEP TEL assessment targets at the corresponding grade level. Each grouping was rated for similarity of content and practices alignment. Groupings of NGSS performance expectations and NAEP content statements indicate overlapping content that was directly compared. "Similar" indicates that two-thirds or more of panelists rated a specific content grouping as similar ("quite similar but with some differences" or "exactly or almost the same"); otherwise, it is "Not Similar." The summary statement column lists the NAEP TEL assessment target(s) that were grouped with each NGSS performance expectation and the primary NAEP TEL practice with which it was aligned. Any performance expectation not aligned to a TEL practice is indicated as "No primary NAEP TEL practice." (See the NAEP TEL framework (NAGB 2013b) for the full description of assessment targets and practices.)

(2) **NGSS science performance expectations with connections to ETS grouped with NAEP TEL assessment targets at the corresponding grade level**. This is the second section of each exhibit. It presents the NGSS science performance expectations with connections to ETS that were grouped with NAEP TEL assessment targets at the corresponding grade level. The process used to determine content similarity ratings and practices alignment for the NGSS science performance expectations with connections to ETS was the same as for the NGSS engineering design performance expectations described above. The summary statement column lists the NAEP TEL assessment target(s) that were grouped with each NGSS performance expectation and the primary NAEP TEL practice. Since the performance expectations in this section were included in both the TEL and science comparisons, the summary statements also indicate any NAEP science content statement(s) that were grouped with each performance expectation and whether these were judged as similar or not similar for science content. (See the NAEP science framework (NAGB 2014b) for the full description of content statements.)

(3) **NGSS performance expectations in ETS not included in the NAEP TEL framework at the corresponding grade level**. This next section in each exhibit presents the NGSS performance expectations that were not grouped with any NAEP TEL assessment target. "NGSS Only" means that panelists agreed that there was no corresponding assessment target in the NAEP TEL framework at the corresponding grade level. Although these NGSS performance expectations were not grouped with any NAEP assessment target(s), they were still judged for alignment with NAEP TEL practices. The primary NAEP TEL practice is identified in the summary statement column. Again, for NGSS science performance expectations with connections to ETS, the summary statements also indicate any NAEP science framework groupings.

(4) **NAEP TEL assessment targets not included in the NGSS ETS discipline at the corresponding grade level**. This is the last section in each exhibit. It presents the NAEP TEL assessment targets (organized by the NAEP assessment subareas) that were not grouped with any NGSS performance expectation. There are two types of TEL assessment targets: those that describe what students should "know" and those that describe what students should "be able to do." The two different types of assessment targets are labeled in the exhibits as "Know" or "Able to." "NAEP Only" means that panelists agreed that there was no NGSS performance expectation at the corresponding grade level with which it could be grouped for direct content comparison.

Exhibit F-1. Content comparison of NGSS performance expectations in engineering, technology, and applications of science (ETS) and NAEP TEL assessment targets: Grades 3-5/grade 4

NGSS Engineering Design Performance Expectations Grouped with NAEP TEL Assessment Target(s) at Grade 4			
Disciplinary Core Idea(s)	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Defining and Delimiting Engineering Problems Influence of Engineering, Technology and Science on Society and the Natural World	3-5-ETS1-1: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.	Similar	Both the NGSS and NAEP TEL include requirements for designs and constraints. Though not explicitly stated, NAEP does include cost as a potential constraint. *NAEP TEL Assessment Target(s)*: D.04.07 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Developing Possible Solutions Influence of Engineering, Technology and Science on Society and the Natural World	3-5-ETS1-2: 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.	Similar	Both the NGSS and NAEP TEL focus on generating multiple solutions. The NGSS more explicitly include comparing multiple solutions than NAEP does. *NAEP TEL Assessment Target(s)*: D.04.06, D.04.07, D.04.08, D.04.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Developing Possible Solutions Optimizing the Design Solution	3-5-ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.	Similar	Both the NGSS and NAEP TEL include testing of a model in order to improve the design. Both also include the concept of fair tests. *NAEP TEL Assessment Target(s)*: D.04.08, D.04.09, D.04.17, D.04.18 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
NGSS Science Performance Expectations with Connections to ETS Grouped with NAEP TEL Assessment Target(s) at Grade 4			
Disciplinary Core Idea(s)	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
ETS: Defining and Delimiting Engineering Problems Influence of Engineering, Technology and Science on Society and the Natural World Conservation of Energy and Energy Transfer Energy in Chemical Processes and Everyday Life	4-PS3-4: Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.	Similar	Both the NGSS and NAEP TEL include design criteria and constraints, as well as testing and improving models. NAEP TEL has a broader scope by not limiting the design to a device. This NGSS performance expectation applies engineering design concepts to a particular problem related to energy conversion. Items/tasks in NAEP TEL would need to provide the necessary science concepts. NAEP science includes energy conversions in electrical circuits at grade 4. *NAEP TEL Assessment Target(s)*: D.04.08, D.04.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals *NAEP Science content statement(s)*: P04.11 (Similar for science)

Optimizing the Design Solution Interdependence of Science, Engineering, and Technology Information Technologies and Instrumentation	4-PS4-3: Generate and compare multiple solutions that use patterns to transfer information.	Similar	Both the NGSS and NAEP TEL focus on generating multiple solutions, although the NGSS more explicitly include comparing multiple solutions than NAEP does. This NGSS performance expectation applies engineering design concepts in a context involving the use of patterns to transfer information. Items/tasks in NAEP TEL would need to provide the necessary science concepts. Using patterns to transfer information is not included in in the NAEP science framework. *NAEP TEL Assessment Target(s)*: D.04.06, D.04.08, D.04.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Interdependence of Science, Engineering, and Technology Influence of Engineering, Technology and Science on Society and the Natural World Natural Resources	4-ESS3-1: Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.	Not Similar	Although both the NGSS and NAEP include the impact of human use of natural resources on the environment, NAEP TEL focuses more on the impact of using technology. Human use of natural resources and the impact on the environment are also included in NAEP science at grade 4. *NAEP TEL Assessment Target(s)*: T.04.05, T.04.07 *NAEP TEL Practice*: Understanding Technological Principles *NAEP Science Content Statement(s):* E04.10, E04.11 (Similar for science)
Designing Solutions to Engineering Problems Influence of Engineering, Technology and Science on Society and the Natural World Natural Hazards	4-ESS3-2: Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.	Similar	Both the NGSS and NAEP TEL focus on generating multiple solutions, although the NGSS more explicitly include comparing multiple solutions than NAEP does. This NGSS performance expectation applies engineering design concepts to a particular problem related to reducing the impact of Earth processes on humans. Items/tasks in NAEP TEL would need to provide the necessary science concepts. NAEP science includes a grade 4 content statement on humans' dependency on the environment, but without the same focus on the impact of Earth processes. *NAEP TEL Assessment Target(s)*: D.04.06, D.04.08, D.04.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals *NAEP Science Content Statement(s):* E04.11 (Not Similar for science)

NGSS Performance Expectations in ETS Not Included in NAEP TEL at Grade 4			
Disciplinary Core Idea(s)	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
None			
NAEP TEL Assessment Targets Not Included in the NGSS ETS Discipline in Grades 3-5			
Assessment Area: Subarea	**Assessment Target**	**Similarity Rating**	**Summary Statement**
Design and Systems: Nature of Technology	D.04.01 (Know): Scientists ask questions about the world; engineers create and modify technologies to meet people's needs and desires.	NAEP Only	NAEP TEL includes 5 assessment targets in the subarea of Nature of Technology that are not reflected in the NGSS. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there is no specific performance expectation in the NGSS related to these concepts. NAEP TEL includes inspecting materials with different properties (D.04.04). While the NGSS include materials as a design constraint, inspecting properties of materials for the purpose of design is not explicitly included in any grade 4 performance expectation.
	D.04.02 (Know): The improvement of existing technologies and the development of new technologies involve creative thinking.	NAEP Only	
	D.04.03 (Know): Tools are simple objects that help people do things better or more easily, such as the cutting, shaping, and combining of materials that occur when making clothing.	NAEP Only	
	D.04.04 (Able to): Inspect materials with different properties and determine which is most suitable for a given application.	NAEP Only	
	D.04.05 (Able to): Choose an appropriate tool for accomplishing a task.	NAEP Only	
Design and Systems: Engineering Design	D.04.10 (Able to): Communicate design ideas using drawings and models.	NAEP Only	NAEP TEL includes one assessment target in the subarea of Engineering Design that is not reflected in the NGSS. Although the NGSS include the use of models for various purposes, it does not specify how design ideas will be communicated (e.g., drawings and models).

Design and Systems: Systems Thinking	D.04.11 (Know): All technological systems require energy and have parts that work together to accomplish a goal.	NAEP Only	NAEP TEL includes 5 assessment targets in the subarea of Systems Thinking. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there is no specific performance expectation in the NGSS related to these concepts.
	D.04.12 (Know): Many systems have subsystems within them and are defined by boundaries. Many systems are parts of larger systems.	NAEP Only	
	D.04.13 (Able to): Given a product, identify its systems, subsystems, and components by taking it apart.	NAEP Only	
	D.04.14 (Able to): Create a diagram of a machine that contains multiple subsystems. Label the subsystems to explain what each one does.	NAEP Only	
	D.04.15 (Able to): Construct a simple system to accomplish a goal, based on knowledge of the function of individual components.	NAEP Only	
Design and Systems: Maintenance and Troubleshooting	D.04.16 (Know): It is important to care for different tools and machines in appropriate ways so that they are available to be used when needed.	NAEP Only	NAEP TEL includes 2 assessment targets in the subarea of Maintenance and Troubleshooting. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there is no specific performance expectation in the NGSS related to these concepts.
	D.04.19 (Able to): Recognize that all products have a life cycle, starting with raw materials and ending with disposal or recycling.	NAEP Only	

Technology and Society: Interaction of Technology and Humans	T.04.01 (Know): People's needs and desires determine which new tools, products, and machines are developed and made available.	NAEP Only	NAEP TEL includes 4 assessment targets in the subarea of Interaction of Technology and Humans. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there is no specific performance expectation in the NGSS related to these concepts.
	T.04.02 (Know): The introduction of a new tool, product, or machine usually brings both benefits and costs, and it may change how people live and work.	NAEP Only	
	T.04.03 (Able to): Identify potential positive and negative effects of the introduction of a new technology into a community.	NAEP Only	
	T.04.04 (Able to): Compare the effects of two different technologies on their own lives by imagining what their lives would be like without those technologies.	NAEP Only	
Technology and Society: Effects of Technology on the Natural World	T.04.06 (Know): Reusing and recycling materials can save money while preserving natural resources and avoiding damage to the environment.	NAEP Only	NAEP TEL includes an assessment target on reuse and recycling. There is no ETS performance expectation in the NGSS explicitly related to this target at grade 4.

Technology and Society: Effects of Technology on the World of Information and Knowledge	T.04.08 (Know): Information technology provides access to vast stores of knowledge and information. This can result in positive and negative effects.	NAEP Only	NAEP TEL includes 4 assessment targets in the subarea of Effects of Technology on the World of Information and Knowledge. While some of the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS in this area.
	T.04.09 (Know): Information technologies can be used to modify and display data in various ways that can be helpful or deceptive.	NAEP Only	
	T.04.10 (Know): Communications technologies make it possible for people to communicate across large distances in writing, voice, and images.	NAEP Only	
	T.04.11 (Able to): Use information and communications technologies to access and interpret data and communicate with others.	NAEP Only	

Technology and Society: Ethics, Equity, and Responsibility	T.04.12 (Know): When using tools and machines, the results can be helpful or harmful.	NAEP Only	NAEP TEL includes 4 assessment targets in the subarea of Ethics, Equity, and Responsibility. This area is not explicitly included in the NGSS.
	T.04.13 (Know): The technologies that people have available for essential tasks such as farming, cooking, medicine, transportation, and communication are vastly different in different parts of the world.	NAEP Only	
	T.04.14 (Able to): Explain the benefits and safe use of a tool or machine by showing how it can and should be used as well as how it should not be used and the consequences that may result if it is used inappropriately.	NAEP Only	
	T.04.15 (Able to): Demonstrate the ethical use of information technologies by recognizing the ways that someone might harm someone else through the misuse of communication technologies, and the kinds of information that could lead to abuse if widely shared.	NAEP Only	

Information and Communication Technology (ICT): Construction and Exchange of Ideas and Solutions	I.04.01 (Know): People collaborating as a team can often produce a better product than people working alone. There are common digital tools that can be used to facilitate virtual or face-to-face collaboration.	NAEP Only	NAEP TEL includes 3 assessment targets in ICT in the subarea of Construction and Exchange of Ideas and Solutions. ICT is not a focus in the NRC K-12 framework or the NGSS. While some of the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS in this area.
	I.04.02 (Able to): Utilize input from (virtual, that is, computer-generated) collaborators and experts or sources in the decision-making process to design a product or presentation.	NAEP Only	
	I.04.03 (Able to): Communicate information and ideas effectively to an audience in order to accomplish a specified purpose.	NAEP Only	
Information and Communication Technology (ICT): Information Research	I.04.04 (Know): Digital and network tools and media resources are helpful for answering questions, but they can sometimes be biased or wrong.	NAEP Only	NAEP TEL includes 3 assessment targets in ICT in the subarea of Information Research. ICT is not a focus in the NRC K-12 framework or the NGSS. While some of the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS in this area.
	I.04.05 (Able to): Use digital and network tools and media resources to collect, organize, and display data in order to answer questions and solve problems.	NAEP Only	
	I.04.06 (Able to): Search media and digital sources on a community issue and identify sources that may be biased.	NAEP Only	

Information and Communication Technology (ICT): Investigation of Problems	I.04.07 (Able to): Use digital tools and resources to identify and investigate a local issue and generate possible solutions.	NAEP Only	NAEP TEL includes 3 assessment targets in ICT in the subarea of Investigation of Problems. ICT is not a focus in the NRC K-12 framework or the NGSS. While the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS that focuses explicitly on the use of digital tools.
	I.04.08 (Able to): Use digital tools to test simple hypotheses in various subject areas.	NAEP Only	
	I.04.09 (Able to): Use digital models to describe how parts of a whole interact with each other in a model of a system.	NAEP Only	
Information and Communication Technology (ICT): Acknowledgment of Ideas and Information	I.04.10 (Know): It is allowable to use other people's ideas in one's own work provided that proper credit is given to the original source, whether information is shared in person or through ICT media.	NAEP Only	NAEP TEL includes 2 assessment targets in ICT in the subarea of Acknowledgement of Ideas and Information. This area is not explicitly included in the NGSS.
	I.04.11 (Able to): Identify or provide examples demonstrating respect for copyrighted material, such as resisting the request from a friend to copy a song from a CD or placing copyrighted material online.	NAEP Only	
Information and Communication Technology (ICT): Selection and Use of Digital Tools	I.04.12 (Know): Different digital tools have different purposes.	NAEP Only	NAEP TEL includes 2 assessment targets in ICT in the subarea of Selection and Use of Digital Tools. ICT is not a focus in the NRC K-12 framework or the NGSS. While some of the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS in this area.
	I.04.13 (Able to): Use digital tools (appropriate for fourth-grade students) effectively for different purposes, such as searching, organizing, and presenting information.	NAEP Only	

Exhibit F-2. Content comparison of NGSS performance expectations in engineering, technology, and applications of science (ETS) and NAEP TEL assessment targets: Middle school/grade 8

NGSS Engineering Design Performance Expectations Grouped with NAEP TEL Assessment Target(s) at Grade 8			
Disciplinary Core Idea(s)	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Defining and Delimiting Engineering Problems Influence of Engineering, Technology and Science on Society and the Natural World	MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	Similar	Both the NGSS and NAEP TEL include identifying design criteria and constraints as well as understanding the effect of resources on possible solutions. NAEP goes beyond the NGSS by explicitly emphasizing the trade-offs between desired features or solutions. *NAEP TEL Assessment Target(s)*: D.08.07, D.08.08, T.08.05 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Developing Possible Solutions	MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	Similar	Both the NGSS and NAEP TEL include evaluating design solutions in order to meet criteria and constraints. The NGSS state a more general approach – a systematic process that goes somewhat beyond NAEP's expectations for constructing and testing a model. *NAEP TEL Assessment Target(s)*: D.08.07, D.08.08, D.08.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Developing Possible Solutions Optimizing the Design Solution	MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	Not Similar	Both the NGSS and NAEP TEL include generating multiple solutions and evaluating solutions. However, NAEP does not include identifying the best characteristics and combining them into a new solution. *NAEP TEL Assessment Target(s)*: D.08.04, D.08.06, D.08.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Developing Possible Solutions Optimizing the Design Solution	MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	Similar	Both the NGSS and NAEP TEL include testing a model and gathering data to refine the design. *NAEP TEL Assessment Target(s)*: D.08.05, D.08.09, D.08.18 *NAEP TEL Practice*: Developing Solutions and Achieving Goals

NGSS Science Performance Expectations with Connections to ETS Grouped with NAEP TEL Assessment Target(s) at Grade 8			
Disciplinary Core Idea(s)	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Interdependence of Science, Engineering, and Technology Influence of Engineering, Technology and Science on Society and the Natural World Structure and Properties of Matter Chemical Reactions	MS-PS1-3: Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.	Not Similar	Although the NGSS and NAEP TEL both include the impact of technology on society, the NGSS performance expectation is focused on the impact of the use of natural resources to produce synthetic materials. NAEP TEL more broadly includes positive and negative impacts from the introduction of new or improved technology. The production and impact of the synthetic materials produced is not explicitly included in the NAEP science framework. *NAEP TEL Assessment Target(s)*: T.08.03 *NAEP TEL Practice*: Understanding Technological Principles
Developing Possible Solutions Optimizing the Design Solution Chemical Reactions	MS-PS1-6: Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.	Similar	Both the NGSS and NAEP TEL include constructing, testing, and refining models in the design process. This NGSS performance expectation applies engineering design concepts to a particular problem related to energy release or absorption by chemical processes. Items/tasks in NAEP TEL would need to provide the necessary science concepts. The concept of exothermic and endothermic reactions is not included at grade 8 in the NAEP science framework. *NAEP TEL Assessment Target(s)*: D.08.06, D.08.08, D.08.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Influence of Engineering, Technology and Science on Society and the Natural World Forces and Motion	MS-PS2-1: Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.	Similar	Both the NGSS and NAEP TEL include designing solutions to solve problems. This NGSS performance expectation applies engineering design concepts to a particular problem involving the application of Newton's Third Law to the motion of colliding objects. Items/tasks in NAEP TEL would need to provide the necessary science concepts. The application of Newton's Third Law to colliding objects is not included at grade 8 in the NAEP science framework. *NAEP TEL Assessment Target(s)*: D.08.06, D.08.08, D.08.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals

Defining and Delimiting Engineering Problems Developing Possible Solutions Definitions of Energy Conservation of Energy and Energy Transfer	MS-PS3-3: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.	Similar	Both the NGSS and NAEP TEL include designing, constructing, testing, and defining models in the design process. This NGSS performance expectation applies both science and engineering principles to the design of a device that minimizes or maximizes thermal energy transfer. Items/tasks in NAEP TEL would need to provide the necessary science concepts. NAEP science includes thermal energy transfer at grade 8. *NAEP TEL Assessment Target(s)*: D.08.06, D.08.08, D.08.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals *NAEP Science Content Statement(s)*: P08.10A (Similar for science)
Developing Possible Solutions Influence of Engineering, Technology and Science on Society and the Natural World Ecosystem Dynamics, Functioning, and Resilience Biodiversity and Humans	MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services.	Similar	Both the NGSS and NAEP TEL include generating and evaluating multiple solutions and considering the impact of humans and technology on the environment. This NGSS performance expectation applies engineering design concepts to a particular problem related to maintaining biodiversity. Any items/tasks in NAEP TEL would need to provide the necessary science concepts related to biodiversity and ecosystems. The NAEP science framework does not have a focus on maintaining biodiversity at grade 8. *NAEP TEL Assessment Target(s)*: D.08.06, D.08.08, T.08.07 *NAEP TEL Practice*: Developing Solutions and Achieving Goals *NAEP Science Content Statement(s)*: L08.08 (Not Similar for science)
Interdependence of Science, Engineering, and Technology Natural Selection	MS-LS4-5: Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.	Not Similar	Although the NGSS and NAEP TEL include the impact of humans on the natural world, this NGSS performance expectation focuses specifically on the impact of technologies on inheritance of traits in organisms. NAEP TEL more broadly includes trade-offs between environmental and economic needs, but the specific science content would not be expected. The NGSS science content is also not included in the NAEP science framework. *NAEP TEL Assessment Target(s)*: T.08.05 *NAEP TEL Practice*: Understanding Technological Principles

Influence of Engineering, Technology and Science on Society and the Natural World Human Impacts on Earth Systems	MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	Similar	Both the NGSS and NAEP TEL include designing solutions to solve problems and the impact of humans on the environment. Human impacts on the environment (positive and negative) are also included in NAEP science at grade 8. *NAEP TEL Assessment Target(s)*: D.08.06, D.08.08 *NAEP TEL Practice*: Developing Solutions and Achieving Goals *NAEP Science Content Statement(s)*: E08.15 (Similar for science)

NGSS Performance Expectations in ETS Not Included in NAEP TEL at Grade 8			
Disciplinary Core Idea(s)	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Influence of Engineering, Technology and Science on Society and the Natural World Information Technologies and Instrumentation	MS-PS4-3: Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.	NGSS Only	The NGSS includes integrating information to support a claim about the reliability of digitized signals. Neither NAEP TEL nor NAEP science include this concept. *NAEP TEL Practice*: Understanding Technological Principles
Interdependence of Science, Engineering, and Technology Structure and Function	MS-LS1-1: Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.	NGSS Only	The NGSS include conducting an investigation to provide evidence of the cellular makeup of living organisms. This performance expectation requires the use of technology to provide scientific evidence. This is not included in the NAEP TEL framework. NAEP science does include the cellular makeup of organisms at grade 8. *NAEP TEL Practice*: No Primary NAEP TEL Practice *NAEP Science Content Statement(s)*: L08.01A (Similar for science)
Interdependence of Science, Engineering, and Technology Earth and the Solar System	MS-ESS1-3: Analyze and interpret data to determine scale properties of objects in the solar system.	NGSS Only	The NGSS include analyzing and interpreting data to determine scale properties of objects in the solar system. This performance expectation requires the use of advanced technology to provide and analyze data. This is not included in NAEP TEL framework. Scale properties of objects in the solar system are also not explicitly included in the NAEP science framework. *NAEP TEL Practice*: No Primary NAEP TEL Practice *NAEP Science Content Statement(s)*: E08.01 (Not Similar for science)
Influence of Engineering, Technology and Science on Society and the Natural World Human Impacts on Earth Systems	MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.	NGSS Only	The NGSS include constructing an argument supported by evidence related to the impact of human population increases and per-capita consumption of natural resources. This specific content is not explicitly included in NAEP TEL or NAEP science frameworks. *NAEP TEL Practice*: No Primary NAEP TEL Practice *NAEP Science Content Statement(s)*: E08.15, L08.07 (Not Similar for science)

NAEP TEL Assessment Targets Not Included in the NGSS ETS Discipline in Middle School			
Assessment Area: Subarea	**Assessment Target**	**Similarity Rating**	**Summary Statement**
Design and Systems: Nature of Technology	D.08.01 (Know): Science is the systematic investigation of the natural world. Technology is any modification of the environment to satisfy people's needs and wants. Engineering is the process of creating or modifying technologies and is constrained by physical laws and cultural norms, and economic resources.	NAEP Only	NAEP TEL includes 3 assessment targets in the subarea of Nature of Technology that are not reflected in the NGSS. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there is no specific performance expectation in the NGSS related to these concepts.
	D.08.02 (Know): Technology advances through the processes of innovation and invention. Sometimes a technology developed for one purpose is adapted to serve other purposes.	NAEP Only	
	D.08.03 (Know): Tools have been improved over time to do more difficult tasks and to do simple tasks more efficiently, accurately, or safely. Tools further the reach of hands, voices, memory, and the five human senses.	NAEP Only	
Design and Systems: Engineering Design	D.08.10 (Able to): Communicate the results of a design process and articulate the reasoning behind design decisions by using verbal and visual means. Identify the benefits of a design as well as the possible unintended consequences.	NAEP Only	NAEP TEL includes one assessment target in the subarea of Engineering Design that is not reflected in the NGSS. Although the NGSS includes the design process, there is no specific performance expectation related to communicating the results of the design process using verbal or visual means.

Design and Systems: Systems Thinking	D.08.11 (Know): Technological systems are designed to achieve goals. They incorporate various processes that transform inputs into outputs. They all use energy in some form. These processes may include feedback and control.	NAEP Only	NAEP TEL includes 5 assessment targets in the subarea of Systems Thinking that are not reflected in the NGSS. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there is no specific performance expectation in the NGSS related to these concepts.
	D.08.12 (Know): Technological systems can interact with one another to perform more complicated functions and tasks than any individual system can do by itself.	NAEP Only	
	D.08.13 (Able to): Examine a product or process through reverse engineering by taking it apart step by step to identify its systems, subsystems, and components, describing their interactions, and tracing the flow of energy through the system.	NAEP Only	
	D.08.14 (Able to): Measure and compare the production efficiency of two machines, a simple machine and a complex machine, designed to accomplish the same goal.	NAEP Only	
	D.08.15 (Able to): Construct and use a moderately complicated system, given a goal for the system and a collection of parts, including those that may or may not be useful in the system.	NAEP Only	

Design and Systems: Maintenance and Troubleshooting	D.08.16 (Know): Many different kinds of products must undergo regular maintenance, including lubrication and replacement of parts before they fail so as to ensure proper functioning.	NAEP Only	NAEP TEL includes 3 assessment targets in the subarea of Maintenance and Troubleshooting that are not reflected in the NGSS. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there is no specific performance expectation in the NGSS related to these concepts.
	D.08.17 (Able to): Diagnose a problem in a technological device using a logical process of troubleshooting. Develop and test various ideas for fixing it.	NAEP Only	
	D.08.19 (Able to): Trace the life cycle of a repairable product from inception to disposal or recycling in order to determine the product's environmental impact.	NAEP Only	
Technology and Society: Interaction of Technology and Humans	T.08.01 (Know): Economic, political, social, and cultural aspects of society drive improvements in technological products, processes, and systems.	NAEP Only	NAEP TEL includes 3 assessment targets in the subarea of Interaction of Technology and Humans that are not reflected in the NGSS. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there is no specific performance expectation in the NGSS related to these concepts.
	T.08.02 (Know): Technology interacts with society, sometimes bringing about changes in a society's economy, politics, and culture, and often leading to the creation of new needs and wants.	NAEP Only	
	T.08.04 (Able to): Compare the impacts of a given technology on different societies, noting factors that may make a technology appropriate and sustainable in one society but not in another.	NAEP Only	
Technology and Society: Effects of Technology on the Natural World	T.08.06 (Know): Resources such as oceans, fresh water, and air—which are essential for life and shared by everyone—are protected by regulating technologies in such areas as transportation, energy, and waste disposal.	NAEP Only	NAEP TEL includes knowledge of regulating technologies in areas such as transportation, energy, and waste disposal. This topic is not explicitly included in the NGSS.

Technology and Society: Effects of Technology on the World of Information and Knowledge	T.08.08 (Know): Information technologies are developing rapidly so that the amount of data that can be stored and made widely accessible is growing at a faster rate each year.	NAEP Only	NAEP TEL includes 4 assessment targets in the subarea of Effects of Technology on the World of Information and Knowledge that are not reflected in the NGSS. While some of the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS in this area.
	T.08.09 (Know): Information technologies make it possible to analyze and interpret data—including text, images, and sound—in ways that are not possible with human senses alone. These uses may result in positive or negative impacts.	NAEP Only	
	T.08.10 (Know): The large range of personal and professional information technologies and communication devices allows for remote collaboration and rapid sharing of ideas unrestricted by geographic location.	NAEP Only	
	T.08.11 (Able to): Use appropriate information and communication technologies to collaborate with others on the creation and modification of a knowledge product that can be accessed and used by other people.	NAEP Only	

Technology and Society: Ethics, Equity, and Responsibility	T.08.12 (Know): Technology by itself is neither good nor bad, but its use may affect others; therefore, decisions about products, processes, and systems must take possible consequences into account.	NAEP Only	NAEP TEL includes 4 assessment targets in the subarea of Ethics, Equity, and Responsibility that are not reflected in the NGSS. This area is not explicitly included in the NGSS.
	T.08.13 (Know): People who live in different parts of the world have different technological choices and opportunities because of such factors as differences in economic resources, location, and cultural values.	NAEP Only	
	T.08.14 (Able to): Explain that it is important for citizens to reduce the negative impacts and increase the positive impacts of their technologies on people in another area or on future generations.	NAEP Only	
	T.08.15 (Able to): Explain why it is unethical to infect or damage other people's computers with viruses or "hack" into other computer systems to gather or change information.	NAEP Only	

Information and Communication Technology (ICT): Construction and Exchange of Ideas and Solutions	I.08.01 (Know): Collaboration can take many forms. Pairs or teams of people can work together in the same space or at a distance, at the same time or at different times, and on creative projects or on technical tasks. Different communications technologies are used to support these different forms of collaboration.	NAEP Only	NAEP TEL includes 3 assessment targets in ICT in the subarea of Construction and Exchange of Ideas and Solutions. ICT is not a focus in the NRC K-12 framework or the NGSS. While some of the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS in this area.
	I.08.02 (Able to): Provide feedback to a (virtual) collaborator on a product or presentation, taking into account the other person's goals and using constructive, rather than negative, criticism.	NAEP Only	
	I.08.03 (Able to): Communicate information and ideas effectively using a variety of media, genres, and formats for multiple purposes and a variety of audiences.	NAEP Only	

Information and Communication Technology (ICT): Information Research	I.08.04 (Know): Increases in the quantity of information available through electronic means and the ease by which knowledge can be published have heightened the need to check sources for possible distortion, exaggeration, or misrepresentation.	NAEP Only	NAEP TEL includes 3 assessment targets in ICT in the subarea of Information Research. ICT is not a focus in the NRC K-12 framework or the NGSS. While some of the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS in this area.
	I.08.05 (Able to): Select and use appropriate digital and network tools and media resources to collect, organize, analyze, and display supporting data to answer questions and test hypotheses.	NAEP Only	
	I.08.06 (Able to): Search media and digital resources on a community or world issue and identify specific examples of distortion, exaggeration, or misrepresentation of information.	NAEP Only	

Information and Communication Technology (ICT): Investigation of Problems	I.08.07 (Able to): Use digital tools to identify a global issue and investigate possible solutions. Select and present the most promising sustainable solution.	NAEP Only	NAEP TEL includes 3 assessment targets in ICT in the subarea of Investigation of Problems. ICT is not a focus in the NRC K-12 framework or the NGSS. While the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS that focuses explicitly on the use of digital tools.
	I.08.08 (Able to): Use digital tools to gather and display data in order to test hypotheses of moderate complexity in various subject areas. Draw and report conclusions consistent with observations.	NAEP Only	
	I.08.09 (Able to): Use a digital model of a system to conduct a simulation. Explain how changes in the model result in different outcomes.	NAEP Only	
Information and Communication Technology (ICT): Acknowledgment of Ideas and Information	I.08.10 (Know): Style guides provide detailed examples for how to give appropriate credit to others when incorporating their ideas, text, or images in one's own work.	NAEP Only	NAEP TEL includes 2 assessment targets in ICT in the subarea of Acknowledgment of Ideas and Information. This area is not explicitly included in the NGSS.
	I.08.11 (Able to): Identify or provide examples of fair use practices that apply appropriate citation of sources when using information from books or digital resources.	NAEP Only	

Information and Communication Technology (ICT): Selection and Use of Digital Tools	I.08.12 (Know): Certain digital tools are appropriate for gathering, organizing, analyzing, and presenting information, while other kinds of tools are appropriate for creating text, visualizations, and models and for communicating with others.	NAEP Only	NAEP TEL includes 2 assessment targets in ICT in the subarea of Selection and Use of Digital Tools. ICT is not a focus in the NRC K-12 framework or the NGSS. While some of the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS in this area.
	I.08.13 (Able to): Use appropriate digital tools to accomplish a variety of tasks, including gathering, analyzing, and presenting information as well as creating text, visualizations, and models and communicating with others.	NAEP Only	

Exhibit F-3. Content comparison of NGSS performance expectations in engineering, technology, and applications of science (ETS) and NAEP TEL assessment targets: High school/grade 12

NGSS Engineering Design Performance Expectations Grouped with NAEP TEL Assessment Target(s) at Grade 12			
Disciplinary Core Idea(s)	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Defining and Delimiting Engineering Problems Influence of Engineering, Technology and Science on Society and the Natural World	HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	Similar	Both the NGSS and NAEP TEL include researching, analyzing, and solving major global challenges at grade 12 and identifying criteria and constraints. NAEP goes somewhat beyond the NGSS by explicitly requiring the development of a systematic plan of investigation and proposing innovative sustainable solutions. *NAEP TEL Assessment Target(s)*: D.12.08, T.12.07, I.12.07 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Optimizing the Design Solution	HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	Not Similar	Although the NGSS and NAEP TEL both include designing solutions to complex real-world problems, only the NGSS explicitly include breaking a larger problem down into smaller, more manageable problems that can be solved through engineering. *NAEP TEL Assessment Target(s)*: D.12.06, D.12.08 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Developing Possible Solutions Influence of Engineering, Technology and Science on Society and the Natural World	HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.	Similar	Both the NGSS and NAEP TEL include designing and evaluating solutions to complex problems based on prioritized criteria and trade-offs, and taking into account social and environmental impacts. NAEP goes somewhat beyond the NGSS by explicitly requiring balancing competing values in selecting the best solution. *NAEP TEL Assessment Target(s)*: D.12.06, D.12.07, D.12.08, T.12.12 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Developing Possible Solutions	HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	Similar	Both the NGSS and NAEP TEL include using models to test and examine the interactions within and between systems in addressing complex problems. NAEP has a broader scope than the NGSS because it does not limit the contrasting and testing of models to the use of computer simulations. On the other hand, the NGSS explicitly require evaluating the interactions between systems. *NAEP TEL Assessment Target(s)*: D.12.06, D.12.08, D.12.09, D.12.13, I.12.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals

NGSS Science Performance Expectations with Connections to ETS Grouped with NAEP TEL Assessment Target(s) at Grade 12			
Disciplinary Core Idea(s)	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Optimizing the Design Solution Chemical Reactions	HS-PS1-6: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.	Not Similar	While both the NGSS and NAEP TEL include optimization of sophisticated design challenges, the NGSS include refining the design of a chemical system, which is not in the NAEP TEL framework. NAEP TEL more broadly includes trade-offs and cost/benefit considerations. This NGSS performance expectation applies engineering design concepts to a particular problem related to chemical equilibrium. Items/tasks in NAEP TEL would need to provide the necessary science concepts. The concept of chemical equilibrium is not included in the NAEP science framework. *NAEP TEL Assessment Target(s)*: D.12.06, D.12.08 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Defining and Delimiting an Engineering Problem Optimizing the Design Solution Forces and Motion	HS-PS2-3: Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.	Not Similar	The NGSS explicitly include applying scientific and engineering principles to design, evaluate, and refine a device. NAEP TEL includes the process of redesigning, constructing, and testing several models to achieve the best solution, but does not have the same focus on refinement as the NGSS. Testing different models in NAEP is more closely aligned with middle school expectations in the NGSS (MS-ETS1-3). This NGSS performance expectation applies engineering design concepts to a particular problem related to forces on colliding objects. Items/tasks in NAEP TEL would need to provide the necessary science concepts. Analysis of forces on colliding objects is included in the NAEP science framework at grade 12. *NAEP TEL Assessment Target(s)*: D.12.06, D.12.08, D.12.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals *NAEP Science Content Statement(s)*: P12.21 (Similar for science)

Defining and Delimiting an Engineering Problem Influence of Engineering, Technology and Science on Society and the Natural World Definitions of Energy Energy in Chemical Processes and Everyday Life	HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.	Similar	Both the NGSS and NAEP TEL include constructing models, as well as testing and refining them in the design process. This NGSS performance expectation applies engineering design concepts to a particular problem related to energy transformation. Items/tasks in NAEP TEL would need to provide the necessary science concepts. The concepts of energy conservation in a system and energy transfer are included in NAEP science. *NAEP TEL Assessment Target(s)*: D.12.06, D.12.08, D.12.09 *NAEP TEL Practice*: Developing Solutions and Achieving Goals *NAEP Science Content Statement(s)*: P12.16 (Not Similar for science)
Influence of Engineering, Technology and Science on Society and the Natural World Wave Properties	HS-PS4-2: Evaluate questions about the advantages of using a digital transmission and storage of information.	Not Similar	Although NAEP TEL includes using digital tools for various purposes, evaluating the advantages of digital transmission and storage of information is not explicitly included in NAEP TEL or NAEP science frameworks. *NAEP TEL Assessment Target(s)*: I.12.12, I.12.13 Understanding Technological Principles
Developing Possible Solutions Ecosystem Dynamics, Functioning, and Resilience Biodiversity and Humans	HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.	Similar	Both the NGSS and NAEP TEL include designing, evaluating, and refining solutions for real-world problems, as well as studying the impact of humans on the environment. This NGSS performance expectation is explicitly about biodiversity. Items/tasks in NAEP TEL would need to provide the necessary science concepts. Biodiversity is not a focus in the NAEP science framework. *NAEP TEL Assessment Target(s)*: D.12.06, D.12.08, D.12.09, T.12.05, T.12.06 *NAEP TEL Practice*: Developing Solutions and Achieving Goals *NAEP Science Content Statement(s)*: L12.07 (Not Similar for science)

Developing Possible Solutions Adaptation Biodiversity and Humans	HS-LS4-6: Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.	Similar	Both the NGSS and NAEP TEL include using models to test solutions and the impact of human activity on the environment. The specific application in this NGSS performance expectation is about using technology to mitigate the impact of human activity on biodiversity. Items/tasks in TEL related to this would need to provide the necessary science concepts. Biodiversity is not a focus in the NAEP science framework. *NAEP TEL Assessment Target(s)*: D.12.06, D.12.08, D.12.09, T.12.05, T.12.06 *NAEP TEL Practice*: Developing Solutions and Achieving Goals *NAEP Science Content Statement(s)*: L12.07B (Not Similar for science)
Influence of Engineering, Technology and Science on Society and the Natural World Natural Resources	HS-ESS3-2: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.	Similar	Both the NGSS and NAEP TEL include evaluating solutions to complex problems, as well as taking into account social and environmental impacts of design solutions and cost-benefit comparisons. Consideration of social impacts and cost-benefit comparisons is not included in NAEP science. *NAEP TEL Assessment Target(s)*: D.12.06, D.12.08, D.12.09, T.12.03, T.12.06 *NAEP TEL Practice*: Developing Solutions and Achieving Goals
Influence of Engineering, Technology and Science on Society and the Natural World Human Impacts on Earth Systems	HS-ESS3-3: Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.	Similar	Both the NGSS and NAEP TEL include creating simulations, models, and representations to communicate ideas; both also include the impact of human activities on society and the environment. The management of natural resources for the sustainability of human populations and biodiversity is not explicitly included in the NAEP science framework. *NAEP TEL Assessment Target(s)*: T.12.05, I.12.09, I.12.13 *NAEP TEL Practice*: Communicating and Collaborating
Influence of Engineering, Technology and Science on Society and the Natural World Human Impacts on Earth Systems	HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.	Similar	Both the NGSS and NAEP TEL include designing, evaluating, and refining solutions for real-world problems; both also include the impact of human activities on the environment. Reducing the impact of humans on natural systems is not a focus in NAEP science at grade 12. *NAEP TEL Assessment Target(s)*: D.12.06, D.12.08, D.12.13, T.12.06 *NAEP TEL Practice*: Developing Solutions and Achieving Goals *NAEP Science Content Statement(s)*: L12.07 (Not Similar for science)

NGSS Performance Expectations in ETS Not Included in NAEP TEL at Grade 12			
Disciplinary Core Idea(s)	**Performance Expectation**	**Similarity Rating**	**Summary Statement**
Developing Possible Solutions[1] Structure and Properties of Matter Types of Interactions	HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.	NGSS Only	The NGSS include communicating scientific and technical information about the functioning of designed materials. This requires conceptual understanding and explanation based on molecular structure, which is excluded in the NAEP TEL framework. The NAEP science framework does include understanding of physical properties of materials based on molecular structure, but the NGSS goes beyond this in terms of the functioning of designed materials. *NAEP TEL Practice*: Communicating and Collaborating *NAEP Science Content Statement(s)*: P12.01 (Not Similar for science)
Interdependence of Science, Engineering, and Technology Influence of Engineering, Technology and Science on Society and the Natural World Energy in Chemical Processes and Everyday Life Wave Properties Electromagnetic Radiation Information Technologies and Instrumentation	HS-PS4-5: Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.	NGSS Only	The NGSS include communicating technical information about how technological devices transmit and capture information and energy. This requires specific science knowledge about waves, which is excluded in the NAEP TEL framework. In NAEP TEL, communication typically focuses on explaining a design or a problem-solving process. This content is also not included in the NAEP science framework. *NAEP TEL Practice*: Communicating and Collaborating

[1] The NGSS identified HS-PS2-6 as integrating science content with engineering through a practice or disciplinary core idea, but did not identify a specific disciplinary core idea from engineering, technology, and applications of science. For the purposes of this table, HS-PS2-6 was assigned to Developing Possible Solutions based on the description in the K-12 framework related to the testing of different materials as part of the engineering design process (NRC 2012, p. 208).

Interdependence of Science, Engineering, and Technology The Universe and Its Stars Electromagnetic Radiation	HS-ESS1-2: Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.	NGSS Only	The NGSS include constructing an explanation of the Big Bang theory using evidence obtained by advanced technology. This requires specific science knowledge, which is excluded in the NAEP TEL framework. In NAEP TEL, explanations usually focus on a design or a problem-solving process. This content is included in the NAEP science framework at grade 12. *NAEP TEL Practice*: No Primary NAEP TEL Practice *NAEP Science Content Statement(s)*: E12.01, E12.02 (Similar for science)
Interdependence of Science, Engineering, and Technology Earth and the Solar System	HS-ESS1-4: Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.	NGSS Only	The NGSS include using mathematical or computational representations to make predictions about the motion of objects in the solar system. This requires specific science knowledge, which is excluded in the NAEP TEL framework. NAEP TEL focuses on using technology to create representations for communication purposes. NAEP science does not focus on a predictive model of the solar system at grade 12. *NAEP TEL Practice*: No Primary NAEP TEL Practice *NAEP Science Content Statement(s)*: P12.22 (Not Similar for science)
Influence of Engineering, Technology and Science on Society and the Natural World Earth Materials and Systems Weather and Climate	HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.	NGSS Only	The NGSS include analyzing geoscience data to make claims related to feedbacks between Earth systems. This requires specific science knowledge, which is excluded in the NAEP TEL framework. NAEP TEL focuses on using technology to analyze and present data for communication purposes. Interpretation of geoscience data and Earth systems is included in the NAEP science framework, although there is not the same level of emphasis on feedbacks. *NAEP TEL Practice*: No Primary NAEP TEL Practice *NAEP Science Content Statement(s)*: E12.10, E12.13 (Not Similar for science)

Interdependence of Science, Engineering, and Technology Earth Materials and Systems Plate Tectonics and Large-Scale System Interactions	HS-ESS2-3: Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	NGSS Only	The NGSS include developing a model based on evidence of Earth's interior obtained using advanced technology. This requires specific science knowledge, which is excluded in the NAEP TEL framework. NAEP science includes a model of Earth's interior and the role of convection at grade 12, but there is not the same focus on different types of evidence as in the NGSS. *NAEP TEL Practice*: No Primary NAEP TEL Practice *NAEP Science Content Statement(s)*: E12.08, E12.09, E12.12A (Not Similar for science)
Influence of Engineering, Technology and Science on Society and the Natural World Natural Resources Natural Hazards	HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.	NGSS Only	The NGSS include constructing an explanation of the influence of natural processes on human activity based on evidence. This requires specific science knowledge, which is excluded in the NAEP TEL framework. NAEP TEL focuses more on the effects of technology on the natural world than the effect of natural systems on human activity. NAEP science includes human dependence on natural ecosystems at grade 12 and emphasizes how natural systems support human life; the effects of natural hazards and climate change in the NGSS performance expectation are not explicitly included. *NAEP TEL Practice*: No Primary NAEP TEL Practice *NAEP Science Content Statement(s)*: E12.13 (Not Similar for science)

NAEP TEL Assessment Targets Not Included in the NGSS ETS Discipline in High School			
Assessment Area: Subarea	**Assessment Target**	**Similarity Rating**	**Summary Statement**
Design and Systems: Nature of Technology	D.12.01 (Know): Advances in science have been applied by engineers to design new products, processes, and systems, while improvements in technology have enabled breakthroughs in scientific knowledge.	NAEP Only	NAEP TEL includes 5 assessment targets in the subarea of Nature of Technology. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 Framework, there is no specific performance expectation in the NGSS related to these concepts. NAEP TEL includes considering trade-offs when selecting a material for an application (D.12.04). The treatment of trade-offs in the NGSS at the high school level is much broader and focused on complex global problems. NAEP TEL includes designing a new tool to accomplish a task more efficiently (D.12.05). The goal of designing tools for increased efficiency is not explicitly included in the NGSS.
	D.12.02 (Know): Engineers use science, mathematics, and other disciplines to improve technology, while scientists use tools devised by engineers to advance knowledge in their disciplines. This interaction has deepened over the past century.	NAEP Only	
	D.12.03 (Know): The evolution of tools, materials, and processes has played an essential role in the development and advancement of civilization, from the establishment of cities and industrial societies to today's global trade and commerce networks.	NAEP Only	
	D.12.04 (Able to): Take into account trade-offs among several factors when selecting a material for a given application.	NAEP Only	
	D.12.05 (Able to): Design a new tool to accomplish a task more efficiently.	NAEP Only	
Design and Systems: Engineering Design	D.12.10 (Able to): Communicate the entire design process from problem definition to evaluation of the final design, taking into account relevant criteria and constraints, including aesthetic and ethical considerations as well as purely logical decisions.	NAEP Only	NAEP TEL includes 1 assessment target in the subarea of Engineering Design that is not reflected in the NGSS. While the NGSS emphasize the design process, there is no specific performance expectation related to communicating the entire design process.

Design and Systems: Systems Thinking	D.12.11 (Know): The stability of a system depends on all of its components and how they are connected, with more complicated systems tending to require more energy and to be more vulnerable to error and failure. Negative feedback loops tend to increase the stability and efficiency of systems.	NAEP Only	NAEP TEL includes 4 assessment targets in the subarea of Systems Thinking. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there is no specific performance expectation in the NGSS related to these concepts.
	D.12.12 (Know): Technological systems are embedded within larger technological, social, natural, and environmental systems.	NAEP Only	
	D.12.14 (Able to): Redesign a complex machine by modifying or rearranging its subsystems in order to optimize its efficiency.	NAEP Only	
	D.12.15 (Able to): Construct and test a manufacturing system composed of several machines to accomplish a given goal. Redesign the system to optimize its efficiency.	NAEP Only	

Design and Systems: Maintenance and Troubleshooting	D.12.16 (Know): Products and structures of various kinds can be redesigned to eliminate frequent malfunctions and reduce the need for regular maintenance.	NAEP Only	NAEP TEL includes 4 assessment targets in the subarea of Maintenance and Troubleshooting. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there is no specific performance expectation in the NGSS related to these concepts.
	D.12.17 (Able to): Analyze a system malfunction using logical reasoning (such as a fault tree) and appropriate diagnostic tools and instruments. Devise strategies and recommend tools for fixing the problem.	NAEP Only	
	D.12.18 (Able to): Analyze a complicated system to identify ways that it might fail in the future. Identify the most likely failure points and recommend safeguards to avoid future failures.	NAEP Only	
	D.12.19 (Able to): Taking into account costs and current trends in technology, identify how long a product should be maintained and repaired and how it might be redesigned to lessen negative environmental impacts.	NAEP Only	

Technology and Society: Interaction of Technology and Humans	T.12.01 (Know): The decision to develop a new technology is influenced by societal opinions and demands. These driving forces differ from culture to culture.	NAEP Only	NAEP TEL includes 3 assessment targets in the subarea of Interaction of Technology and Humans. While these concepts may underlie some of the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NRC K-12 framework, there is no specific performance expectation in the NGSS related to these concepts.
	T.12.02 (Know): Changes caused by the introduction and use of a new technology can range from gradual to rapid and from subtle to obvious, and can change over time. These changes may vary from society to society as a result of differences in a society's economy, politics, and culture.	NAEP Only	
	T.12.04 (Able to): Analyze cultural, social, economic, or political changes (separately or together) that may be triggered by the transfer of a specific technology from one society to another. Include both anticipated and unanticipated effects.	NAEP Only	

Technology and Society: Effects of Technology on the World of Information and Knowledge	T.12.08 (Know): Information technology allows access to vast quantities of data, expertise, and knowledge through a wide array of devices and formats to answer questions, solve problems, and inform the decision-making process.	NAEP Only	NAEP TEL includes 4 assessment targets in the subarea of Effects of Technology on the World of Information and Knowledge. While some of the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS in this area.
	T.12.09 (Know): Information technologies such as artificial intelligence, image enhancement and analysis, and sophisticated computer modeling and simulation create new types of information that may have profound effects on society. These new types of information must be evaluated carefully.	NAEP Only	
	T.12.10 (Know): The development of communication technologies that enable people to access vast quantities of information and publish their ideas globally has implications for governments, organizations, and individuals.	NAEP Only	
	T.12.11 (Able to): Give examples to illustrate the effects on society of the recording, distribution, and access to information and knowledge that have occurred in history, and discuss the effects of those revolutions on societal change.	NAEP Only	

Technology and Society: Ethics, Equity, and Responsibility	T.12.13 (Know): Disparities in the technologies available to different groups of people have consequences for public health and prosperity, but deciding whether to introduce a new technology should consider local resources and the role of culture in acceptance of the new technology.	NAEP Only	NAEP TEL includes 3 assessment targets in the subarea of Ethics, Equity, and Responsibility. This area is not explicitly included in the NGSS.
	T.12.14 (Able to): Analyze responsibilities of individuals and groups, ranging from citizens and entrepreneurs to political and government officials, with respect to a controversial technological issue.	NAEP Only	
	T.12.15 (Able to): Demonstrate the responsible and ethical use of information and communication technologies by distinguishing between kinds of information that should and should not be publicly shared and describing the consequences of a poor decision.	NAEP Only	

Information and Communication Technology (ICT): Construction and Exchange of Ideas and Solutions	I.12.01 (Know): Effective collaboration requires careful selection of team members, monitoring of progress, strategies for reaching agreement when there are opposing points of view, and iterative improvement of collaborative processes. Information and communication technologies can be used to record and share different viewpoints and to collect and tabulate the views of groups of people.	NAEP Only	NAEP TEL includes 3 assessment targets in ICT in the subarea of Construction and Exchange of Ideas and Solutions. ICT is not a focus in the NRC K-12 framework or the NGSS. While some of the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS in this area.
	I.12.02 (Able to): Work through a simulation of a collaborative process. Negotiate team roles and resources, draw upon the expertise and strengths of other team members and remote experts, monitor progress toward goals, and reflect on and refine team processes for achieving goals.	NAEP Only	
	I.12.03 (Able to): Synthesize input from multiple sources to communicate ideas to a variety of audiences using various media, genres, and formats.	NAEP Only	

Information and Communication Technology (ICT): Information Research	I.12.04 (Know): Advanced search techniques can be used with digital and network tools and media resources to locate information and to check the credibility and expertise of sources.	NAEP Only	NAEP TEL includes 3 assessment targets in ICT in the subarea of Information Research. ICT is not a focus in the NRC K-12 framework or the NGSS. While some of the knowledge and skills in the TEL targets may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS in this area.
	I.12.05 (Able to): Select digital and network tools and media resources to gather information and data on a practical task, and justify choices based on the tools' efficiency and effectiveness for a given purpose.	NAEP Only	
	I.12.06 (Able to): Search media and digital resources on a community or world issue and evaluate the timeliness and accuracy of the information as well as the credibility of the source.	NAEP Only	

Information and Communication Technology (ICT): Investigation of Problems	I.12.08 (Able to): Use digital tools to collect, analyze, and display data in order to design and conduct complicated investigations in various subject areas. Explain rationale for the design and justify conclusions based on observed patterns in the data.	NAEP Only	NAEP TEL includes using digital tools to collect, analyze, and display data in order to design and conduct complicated investigations. While the knowledge and skills in this TEL target may be used when applying the scientific and engineering practices, there is no specific performance expectation in the NGSS that focuses explicitly on the use of digital tools.
Information and Communication Technology (ICT): Acknowledgment of Ideas and Information	I.12.10 (Know): Legal requirements governing the use of copyrighted information and ethical guidelines for appropriate citations are intended to protect intellectual property.	NAEP Only	NAEP TEL includes 2 assessment targets in ICT in the subarea of Acknowledgement of Ideas and Information. This area is not explicitly included in the NGSS.
	I.12.11 (Able to): Identify or provide examples of responsible and ethical behavior that follow the letter and spirit of current laws concerning personal and commercial uses of copyrighted material as well as accepted ethical practices when using verbatim quotes, images, or ideas generated by others.	NAEP Only	

Appendix G: Content Comparison of NGSS Mathematics-Related Practices and NAEP Mathematics Framework Objectives

Appendix G includes detailed content comparisons of NGSS mathematics-related performance expectations[1] and practices and NAEP mathematics framework objectives. There are three exhibits, one for each grade level:

G-1: Grade 4

G-2: Middle School

G-3: High School

These exhibits identify the NGSS mathematics-related performance expectations for each scientific and engineering practice at each grade level together with the NAEP mathematics content areas and grades that include objectives that were judged as aligned. Summary statements describe the type of mathematics that may be required on items and tasks developed to assess the NGSS performance expectations and the mathematics expectations of aligned NAEP objectives. These are based on discussions during the expert panel meeting; information provided in the NGSS (descriptions of performance expectations, clarification statements, assessment boundaries, elements of the underlying disciplinary core ideas from the NRC K-12 framework, connections to Common Core State Standards for Mathematics (CCSS-M), and definitions of grade-specific practice components); and information in the NAEP mathematics framework and assessment and item specifications (grade-specific boundaries and clarifications on mathematics and subtopics).

[1] The eight NGSS performance expectations are the following: (1) asking questions (for science) and defining problems (for engineering), (2) developing and using models, (3) planning and carrying out investigations, (4) analyzing and interpreting data, (5) using mathematics and computational thinking, (6) constructing explanations (for science) and designing solutions (for engineering), (7) engaging in argument from evidence, and (8) obtaining, evaluating, and communicating information.

There are three main columns in each exhibit:

(1) **NGSS Mathematics-Related Practices and NGSS Performance Expectation(s)**.This column describes the mathematics-related practices included in each main NGSS scientific and engineering practice. The associated performance expectations that require the mathematics-related practices are listed.[2] The number in parentheses refers to the grade-specific component of the practice. For example, (1.5) in the first row of the table in exhibit G-1 refers to the fifth bullet under the first NGSS practice of *asking questions and defining problems* for the 3-5 grade band.[3]

(2) **Alignment with NAEP Mathematics Framework Objectives**. This column lists the NAEP mathematics content areas (by grade) that include objectives aligned with any of the NGSS performance expectation(s) in a given NGSS mathematics-related practice. Alignment indicates that the panel as a group judged a NGSS performance expectation as aligned with one or more objective(s) in the NAEP mathematics framework.

(3) **Summary Statement**. This column provides summaries of (i) the NGSS performance expectations included for each NGSS mathematics-related practice component; (ii) the content and skills covered by NAEP mathematics objectives aligned with the NGSS performance expectations at the corresponding grade level; and, where appropriate, (iii) the content and skills covered by NAEP mathematics objectives from the next higher or lower grade level in the NAEP framework that were aligned with the NGSS performance expectations.

[2] As described in the methods section for mathematics comparisons in the body of the report (section 3.3), the mathematics-related performance expectations were those identified in the NGSS as having connections to the Common Core State Standards for Mathematics (CCSS-M). There were seven middle school and two high school performance expectations identified in the NGSS as having connections to the CCSS-M that were judged as not being aligned to any NAEP mathematics objective (MS-LS1-1, MS-LS1-2, MS-LS1-3, MS-LS1-6, MS-LS4-2, MS-ESS2-3, MS-ESS3-1, HS-PS2-5, and HS-LS1-4). These performance expectations are not reflected in the Appendix G exhibits.

[3] See appendix F in the *Next Generation Science Standards: For States, By States* (NGSS Lead States 2013) for more detail on the components of each scientific and engineering practice. The first digit identifies the practice number, and the second digit refers to the bullet number of the appropriate grade-specific component.

Exhibit G-1. Content comparison of NGSS mathematics-related practices and NAEP mathematics framework objectives: Grade 4

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
1. Asking questions (for science) and defining problems (for engineering)		
Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (1.5) 3-5-ETS1-1	Grade 4: Number, Measurement, Algebra, Data Grade 8: Number, Measurement	The NGSS include a performance expectation in engineering design for defining a simple design problem that includes specified criteria for success and constraints on materials, time, or cost. The specific mathematics required will depend on the particular science context and design problem to be solved. This performance expectation may be aligned with several different grade 4 objectives in the NAEP mathematics framework related to calculation of constraints and estimation, understanding attributes and units of criteria, reading constraints from charts and tables, and communicating possible relationships among constraints. Criteria expressed in percentages and rates are more consistent with grade 8 standards in the NAEP framework.
2. Developing and using models		
Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. (2.3) 4-PS4-1	Grade 4: Number, Measurement, Geometry, Algebra Grade 8: Geometry	The NGSS include the process of developing a model of waves to describe patterns in terms of amplitude and wavelength and the concept that waves can cause objects to move. This is aligned with several different grade 4 objectives in the NAEP mathematics framework related to computation; measuring attributes such as length, time, capacity, or weight in problem-solving situations; describing paths between points; and symbolic representation of unknown quantities. The actual representation of the geometrical model indicated in the NGSS performance expectation may require some mathematics that is more consistent with grade 8 in the NAEP framework.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Develop and/or use models to describe and/or predict phenomena. (2.4) 4-PS4-2	Grade 4: Geometry Grade 8: Geometry	The NGSS include developing a model to describe that light reflecting from objects and entering the eye allows objects to be seen. This is aligned with grade 4 geometry objectives in the NAEP mathematics framework related to properties of paths between points; drawing angles; and identifying images resulting from reflections, translations, and rotations. Describing the effect of reflection may require some mathematics that is more consistent with grade 8 in the NAEP framework.
3. Planning and carrying out investigations		
Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3.1) 3-5-ETS1-3	Grade 4: Number, Measurement, Geometry, Algebra, Data Grade 8: Number, Measurement, Geometry, Algebra, Data	The NGSS include a performance expectation in engineering design for planning and carrying out fair tests in which variables are controlled and failure points considered to identify aspects of a model or prototype that can be improved. The specific mathematics required will depend on the particular science context and design problem to be solved. This performance expectation may be aligned with NAEP grade 4 objectives across all content areas related to diagrams, models, scale models, graphical models and mathematical models, geometric properties (perpendicularity and parallelism), representing data in tables, and using patterns as representations for sharing design ideas and results. Criteria for a fair test, communicating results, comparisons across data sets, identifying data which may be suspect (outliers), and considering the mean as a parameter may be aligned with mathematics that is more consistent with grade 8 objectives.
Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3.3) 4-ESS2-1	Grade 4: Number, Measurement, Algebra, Data Grade 8: Measurement, Algebra, Data	The NGSS include making observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. This is aligned with NAEP grade 4 objectives related to proportional reasoning, measuring attributes, reading and interpreting data, recognizing patterns, and representing a relationship symbolically, numerically, pictorially, or verbally. Working with attributes like rates and characteristics of data sets (mean, median, mode, and range) in order to understand and explain the phenomena require mathematics that is more consistent with grade 8 objectives in the NAEP framework.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
4. Analyzing and interpreting data		
Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation. (4.2) 4-ESS2-2	Grade 4: Number, Algebra	The NGSS include analyzing and interpreting data from maps to describe patterns of Earth's features. This is aligned with NAEP grade 4 objectives related to graphing, interpreting points on a grid, and solving real-world problems involving numbers.
5. Using mathematics and computational thinking		
NONE		
6. Constructing explanations and designing solutions		
Identify the evidence that supports particular points in an explanation. (6.3) 4-ESS1-1	Grade 4: Measurement Grade 8: Measurement	The NGSS include identifying evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time. This is aligned with grade 4 measurement objectives in the NAEP mathematics framework related to measuring attributes such as length, time, capacity, or weight in problem-solving situations. The large time scale indicated in the NGSS performance expectation may require some mathematics that is more consistent with grade 8 in the NAEP framework.
Apply scientific ideas to solve design problems. (6.4) 4-PS3-4	Grade 4: Number, Measurement, Geometry, Data Grade 8: Number, Measurement	The NGSS include applying scientific ideas to design, test, and refine a device that converts energy from one form to another. This is aligned with grade 4 objectives related to numerical operations, using ratios to describe problem situations, measuring attributes, selecting appropriate units, identifying paths between points, drawing angles, representing data in tables and graphs, and verifying reasonableness of solutions. Attributes like area, volume, and mass indicated in the NGSS performance expectation may require some mathematics that is more consistent with grade 8 in the NAEP framework.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. (6.5) 4-PS4-3 4-ESS3-2 3-5-ETS1-2	Grade 4: Number, Measurement, Geometry, Algebra, Data Grade 8: Number, Measurement, Geometry, Algebra, Data	The NGSS include a performance expectation in engineering design for generating and comparing multiple solutions to a problem based on how well they meet the criteria and constraints of the design (the specific mathematics required will depend on the particular science context and design problem to be solved). In addition, performance expectations in physical sciences and Earth and space sciences are included that apply this practice specifically to the use of patterns to transfer information and reducing the impacts of natural Earth processes on humans. These performance expectations are aligned with grade 4 objectives across the content areas related to diagrams, models, scale models, graphical and mathematical models, criteria and constraints in the design process, measuring of attributes, conversion in scaling up from models, and geometric properties (perpendicularity and parallelism). Representing data, observing patterns in the data, representing ideas symbolically, communicating results, comparing across data sets, identifying data that may be suspect (outliers), and considering the mean as a parameter may be better aligned with grade 8 objectives.
7. Engaging in argument from evidence		
Construct and/or support an argument with evidence, data, and/or a model. (7.4) 4-LS1-1	Grade 4: Geometry Grade 8: Geometry	The NGSS include constructing an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. This is aligned with grade 4 geometry objectives in the NAEP mathematics framework related to properties of geometric figures and symmetry of figures. Working with cross-sections of organs may require mathematics that is more consistent with grade 8 mathematics.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
8. Obtaining, evaluating, and communicating information		
Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem. (8.4) 4-ESS3-1	Grade 4: Number, Measurement, Data Grade 8: Number, Measurement	The NGSS include obtaining and combining information to describe that energy and fuels are derived from natural resources and their uses affect the environment. This is aligned with grade 4 objectives related to using simple ratios to describe problem situations, measuring attributes, using appropriate units for the attributes, representing the solutions in a table or graph, describing solutions using some properties, comparing the results from two different occasions, verifying solutions, and determining the reasonableness of results in meaningful contexts. Working with attributes like mass or weight in terms of resources and working with information obtained from computers may require mathematics that is more consistent with grade 8 objectives in the NAEP framework.

Exhibit G-2. Content comparison of NGSS mathematics-related practices and NAEP mathematics framework objectives: Middle school

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
1. Asking questions (for science) and defining problems (for engineering)		
Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument. (1.2) MS-ESS3-5	Grade 8: Data Grade 12: Data	The NGSS include asking questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. This is aligned with NAEP grade 8 data objectives related to reading and interpreting data available on global warming, representing data visually, solving problems using data, determining if the information is represented appropriately, and comparing and contrasting different representation of data to form an argument. Critiquing different ways of presenting and using information may be aligned with mathematics that is more consistent with grade 12 objectives in the NAEP framework.
Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. (1.6) MS-PS2-3	Grade 8: Number, Measurement, Algebra, Data	The NGSS include asking questions about data to determine the factors that affect the strength of electric and magnetic forces. This is aligned with NAEP grade 8 objectives related to operating with numbers; proportional reasoning; problems involving speed; using appropriate units during calculation; reading and interpreting data from tables, charts, and graphs; representing information appropriately; comparing and contrasting different representation of data to ask questions; extending and generalizing patterns observed in the data; and expressing the relationship (linear or non-linear) between quantities as observed in the data in tables, graphs, charts, or words.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (1.8) MS-ETS1-1	Grade 8: Number, Measurement, Algebra, Data Grade 12: Data	The NGSS include a performance expectation in engineering design for defining the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, while taking into account relevant scientific principles and potential impacts on people and the natural environment. The specific mathematics required will depend on the particular science context and design problem to be solved. This performance expectation may be aligned with NAEP grade 8 objectives related to computing with numbers, models, scale models, geometrical models, and algebraic models; representing data in tables; and using patterns as representations for sharing design ideas and results. In addition, precision to ensure correct solutions requires objectives related to measurement. Working with multiple constraints and criteria may involve mathematics that is more consistent with NAEP grade 12 mathematics.
2. Developing and using models		
Develop and/or use a model to predict and/or describe phenomena. (2.5) MS-PS1-1 MS-PS1-4 MS-PS4-2 MS-LS2-3 MS-LS3-2 MS-ESS1-1 MS-ESS1-2 MS-ESS2-1 MS-ESS2-6	Grade 8: Number, Measurement, Geometry, Algebra, Data Grade 12: Geometry	The NGSS require developing, and/or using a model to predict or describe phenomena between different systems or components of a system. This practice has performance expectations in all three content domains: physical sciences, life sciences, and Earth and space sciences. Specific examples of models include atomic structure; cycling of matter; asexual and sexual reproduction; Earth-sun-moon system; waves; changes of state related to thermal energy transfer; climate change; and the role of gravity in planetary and galaxy motion. These performance expectations are aligned with NAEP grade 8 objectives related to models, scale models, geometrical models, and algebraic models; proportional reasoning; measuring physical attributes including rates; transformation of shapes; using probability to predict experimental outcomes; recognizing patterns in outcomes; graphing the relationship observed in the data; and translating between different representations of the same data. Specifically, a model that shows how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates may need vectors to represent forces. The concept of vectors is more consistent with NAEP grade 12 mathematics.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Develop a model to describe unobservable mechanisms. (2.6) MS-PS1-5 MS-PS3-2 MS-LS1-7 MS-ESS2-4	Grade 8: Number, Measurement, Geometry, Algebra, Data Grade 12: Algebra	The NGSS require developing a model to describe unobservable mechanisms. This practice has performance expectations in all three content domains: physical sciences, life sciences, and Earth and space sciences. Specific examples of models include unchanged number of atoms during a chemical reaction, change in potential energy when the arrangement of objects change, rearrangement of food through chemical reactions to form new molecules that support growth and/or release energy, and the water cycle. These performance expectations are aligned with NAEP grade 8 objectives related to comparing objects with different attributes; using appropriate measuring instruments for the attributes and appropriate units; and problems involving proportional reasoning, rates, geometric models, and geometric properties (parallelism and perpendicularity). In addition, representing data in tables, graphs, and charts; comparing different representations of the same data; recognizing patterns in the data; generalizing the pattern in the data; and representing the relationship observed in data symbolically were also aligned with NAEP grade 8 objectives. Expressing energy released from food may require some mathematics that is more consistent with the NAEP grade 12 objectives.
Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (2.7) MS-ETS1-4	Grade 8: Number, Measurement, Geometry, Algebra, Data Grade 12: Algebra, Data	The NGSS include a performance expectation in engineering design for developing a model to generate data for iterative testing and modifying a proposed object, tool, or process to achieve an optimal design. The specific mathematics required will depend on the particular science context and design problem to be solved. This performance expectation may be aligned with several different NAEP grade 8 objectives related to number operations; modeling; estimation; measuring physical attributes; selecting appropriate units and accuracy of measurement; representing data in tables, charts, and graphs; using statistical parameters to describe and compare multiple data sets; recognizing and generalizing patterns in the data; representing relationships between quantities verbally or symbolically; and solving equations and inequalities. Working with situations involving logarithmic or exponential functions and organizing data in spreadsheets requires mathematics that is more consistent with NAEP grade 12 objectives.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
3. Planning and carrying out investigations		
Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. (3.1) MS-PS2-2 MS-PS3-4	Grade 8: Number, Measurement, Algebra, Data	The NGSS include planning an investigation to provide evidence. This practice has two performance expectations in the area of physical sciences. One is that an object's motion depends on the sum of the forces on the object and the mass of the object. The other is to determine the relationships in the energy transfer, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. These performance expectations are aligned with NAEP grade 8 objectives related to using appropriate measuring instruments to measure an attribute, solving problems using indirect measures, displaying and interpreting data from the investigation, and developing mathematical model for the data obtained.
Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. (3.4) MS-ESS2-5	Grade 8: Data	The NGSS include collecting data to provide evidence for how the motion and complex interactions of air masses result in changes in weather conditions. This is aligned with NAEP grade 8 data objectives related to estimating the probability of an event in order to solve problems.
4. Analyzing and interpreting data		
Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. (4.1) MS-PS3-1	Grade 8: Number, Measurement, Algebra, Data	The NGSS include constructing and interpreting graphical displays of data to describe the relationships of kinetic energy to the mass and speed of an object. This is aligned with objectives from the NAEP mathematics framework related to using proportional reasoning to model situations; solving problems involving rates (speed); solving problems with estimating and computing with data; recognizing and extending patterns in the data; understanding the mathematical vocabulary associated with functions (slope and intercept); and analyzing relationships expressed in tables or graphs.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Analyze and interpret data to provide evidence for phenomena. (4.4) MS-LS2-1	Grade 8: Number, Measurement, Algebra, Data Grade 12: Algebra, Data	The NGSS include analyzing and interpreting data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. This NGSS performance expectation is aligned with objectives from the grade 8 NAEP framework related to measuring physical attributes; selecting appropriate units and accuracy of measurement; representing data in tables, charts, and graphs; describing and comparing multiple data sets with statistical parameters; evaluating the design of experiments used to collect data; recognizing patterns in the data; generalizing patterns; representing relationships as functions; and understanding the meaning of slope and intercept. In addition, number operations, modeling, and estimation are aligned with objectives from the grade 8 NAEP framework. Working with non-linear relationships (quadratic, logarithmic, and exponential) as well as reasoning with data may require mathematics that is more consistent with grade 12 objectives in the NAEP framework.
Analyze and interpret data to determine similarities and differences in findings. (4.7) MS-PS1-2 MS-LS4-1 MS-ESS1-3 MS-ESS3-2 MS-ETS1-3	Grade 8: Number, Measurement, Geometry, Algebra, Data Grade 12: Algebra, Data	The NGSS include a performance expectation in engineering design to analyze experimental data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success (the specific mathematics required will depend on the particular science context and design problem to be solved). In addition, this practice includes performance expectations involving analyzing and interpreting data from all three content domains: physical sciences, life sciences, and Earth and space sciences. Specific examples include properties of substances before and after the substances interact, patterns in the fossil record, scale properties of objects in the solar system, and the use of natural hazards to forecast future catastrophic events. These performance expectations are aligned with NAEP grade 8 objectives related to computing with rational numbers; modeling with numbers; measuring physical attributes; using data representation and statistical parameters; evaluating experimental designs; recognizing patterns in data; generalizing these patterns as functions; and understanding the meaning of slope and intercept in interpreting relationships. The use of logarithmic or exponential functions and data organized in spreadsheets requires mathematics that is more consistent with grade 12 mathematics.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
5. Using mathematics and computational thinking		
Use mathematical representations to describe and/or support scientific conclusions and design solutions. (5.2) MS-PS4-1 MS-LS4-6	Grade 8: Number, Measurement, Algebra, Data Grade 12: Algebra	The NGSS require using mathematical representations to describe or support scientific explanations. This practice has performance expectations both in the area of physical sciences and life sciences. Specific examples include phenomena of waves and natural selection. These performance expectations are aligned with NAEP grade 8 objectives related to ordering numbers; using proportional reasoning; problems involving rates; representing data in tables, charts, and graphs; describing data using measures of central tendency (mean, median, and mode) or spread (range); interpreting probability within a context; graphing the bivariate data; and working with linear and nonlinear functions. Changes in population may require mathematics (using rate of change) that is more consistent with NAEP grade 12 objectives.
6. Constructing explanations and designing solutions		
Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. (6.1) MS-LS2-2 MS-LS4-4	Grade 8: Number, Measurement, Algebra, Data	The NGSS require constructing an explanation based on evidence that predicts or describes phenomena. Specific examples of the phenomena include patterns of interactions among organisms across multiple ecosystems, and genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. These performance expectation are aligned with NAEP grade 8 objectives related to proportional reasoning; working with rates; calculating and describing typical values and range of data; understanding the role of outliers; and using appropriate statistical measures (e.g., mean, median, or mode) to compare two different data sets. Recognizing patterns in data sets; generalizing the pattern observed in the given data; creating a rule or mathematical expression; and identifying relationships as linear or nonlinear are also concepts that are aligned with NAEP grade 8 objectives.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (6.3) MS-LS1-5 MS-ESS1-4 MS-ESS2-2	Grade 8: Number, Data	The NGSS require constructing a scientific explanation based on valid and reliable evidence. This practice has performance expectations in both the life sciences and Earth and space sciences. Specific examples include the influence of environmental and genetic factors on the growth of organisms, the use of geologic time scale to organize Earth's 4.6-billion-year history, and changes in Earth's surface caused by geoscience processes. These performance expectations are aligned with grade 8 objectives from the NAEP mathematics framework related to using mathematical models (number lines and diagrams), working with very large and small numbers, using proportional reasoning to model situations, displaying data, solving problems displaying data, and using appropriate statistical measures to compare two different data sets.
Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. (6.6) MS-PS2-1 MS-PS3-3 MS-ESS3-3	Grade 8: Number, Measurement, Geometry, Algebra, Data Grade 12: Algebra, Data	The NGSS require applying scientific ideas or principles to design, construct, or test the design of a device or process. This practice has performance expectations in both the areas of physical sciences and Earth and space sciences. Specific examples include Newton's Third Law, thermal energy transfer, and human impact on the environment. These performance expectations are aligned with NAEP grade 8 objectives related to using mathematical models; using proportional reasoning; measuring physical attributes; selecting appropriate units and accuracy; representing data; analyzing characteristics of data sets (e.g., mean, median, mode, or range); recognizing patterns in data; generalizing patterns; representing the relationships observed in these patterns as functions; and understanding the meaning of slope and intercept in interpreting relationships. Situations involving non-linear relationships (e.g., quadratic, logarithmic, or exponential functions) and data organized in spreadsheets require mathematics that is more consistent with NAEP grade 12 objectives.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. (6.7) MS-PS1-6	Grade 8: Number, Measurement, Geometry, Algebra, Data	The NGSS include a performance expectation in physical sciences that requires undertaking a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes This performance expectation is aligned with NAEP grade 8 objectives related to the measurement of physical attributes, using appropriate units, accuracy of measurement, data representation, characteristics of data sets, recognizing patterns in the data, generalizing these patterns and representing them as functions, understanding the meaning of slope and intercept, and translating between different representations of linear expressions. In addition, the use of geometric models and proportional reasoning are also aligned with NAEP Grade 8 objectives.
7. Engaging in argument from evidence		
Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (7.3) MS-PS2-4 MS-PS3-5 MS-LS1-4 MS-LS2-4 MS-ESS3-4	Grade 8: Number, Measurement, Algebra, Data Grade 12: Algebra, Data	The NGSS require constructing and presenting arguments using evidence to support or refute an explanation or model of a phenomenon. This practice has performance expectations in all three content domains: physical sciences, life sciences, and Earth and space sciences. Specific examples of the phenomena include gravitational interactions, transfer of energy from one object to another, animal behaviors and specialized plant structures that affect the probability of successful reproduction, how changes to physical or biological components of an ecosystem affect populations, and how consumption of natural resources impacts Earth's systems. These performance expectations are aligned with NAEP grade 8 objectives related to mathematical models, scale models, geometric models, and proportional reasoning. In addition, measuring physical attributes, selecting appropriate units and degree of accuracy, generalizing patterns, representing the relationships observed in these patterns as functions, and understanding the meaning of slope and intercept are also aligned with NAEP grade 8 objectives. Situations involving the use of non-linear relationships (e.g., quadratic, logarithmic, or exponential functions) and data organized into spreadsheets require mathematics that is more consistent with NAEP grade 12 objectives.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (7.5) MS-LS2-5 MS-ETS1-2	Grade 8: Number, Measurement, Geometry, Algebra, Data Grade 12: Algebra, Data	The NGSS include a performance expectation in engineering design for using a systematic process to determine how well the processes meet the criteria and constraints of the problem (the specific mathematics required will depend on the particular science context and design problem to be solved). An additional performance expectation in the life sciences involves the application of this practice to maintain biodiversity and ecosystem services. The specific mathematics required will depend on the particular science context and design problem to be solved. These performance expectations may be aligned with NAEP grade 8 objectives related to using mathematical models, scale models, and geometric models; using proportional reasoning; measuring physical attributes; selecting the appropriate size of the unit and degree of accuracy; representing data; using the characteristics of data sets; recognizing patterns in the data; generalizing patterns; and representing the relationships observed in these patterns as functions. Situations involving the use of non-linear relationships (e.g., quadratic, logarithmic, or exponential functions) and organization of data in spreadsheets require mathematics that is more consistent with NAEP grade 12 objectives.
8. Obtaining, evaluating, and communicating information		
NONE		

Exhibit G-3. Content comparison of NGSS mathematics-related practices and NAEP mathematics framework objectives: High school

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
1. Asking questions (for science) and defining problems (for engineering)		
Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. (1.8) HS-ETS1-1	Grade 12: Number, Measurement, Geometry, Algebra, Data	The NGSS have a performance expectation in engineering design that includes analyzing a global challenge to specify qualitative and quantitative criteria and constraints for solutions addressing societal needs and wants. This performance expectation is aligned with a number of NAEP grade 12 objectives across all five mathematics content areas. The type of mathematics required will depend on the specific problem-solving situation and science principles involved. Objectives related to various types of numbers (real numbers, including expressions utilizing exponents, fractional powers, and logarithms; very large numbers; and proportions, rates, and compound percentages) and their computations are needed for analysis. Measurement objectives are needed to support reasoning based on measured quantities and assigning meaningful units. Objectives related to geometric models may be needed to describe criteria or physical characteristics of objects or quantities. Data objectives support working with different representations (charts, graphs, tables, and spreadsheets) as well as using statistical parameters of statistics as criteria. Algebra objectives are needed to make inferences from data using an algebraic model (equations; inequalities; polynomial and rational expressions; or functions, including logarithmic, trigonometric, and exponential).

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
2. Developing and using models		
Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. (2.3) HS-PS1-4 HS-PS1-8 HS-PS3-2 HS-PS3-5 HS-LS2-5 HS-ESS1-1 HS-ESS2-1 HS-ESS2-3 HS-ESS2-6	Grade 8: Number Grade 12: Number, Measurement, Geometry, Algebra, Data	The NGSS include developing, revising, or using a model to illustrate or describe relationships between different systems or between components of a system. This practice has performance expectations in all three content domains: physical sciences, life sciences, and Earth and space sciences. Specific examples of models include changes in the energy of a system during chemical reactions, nuclear reactions, motion of particles, and interactions of electric or magnetic forces. This practice also includes modeling the cycling of matter during photosynthesis and cellular respiration, and Earth's internal and surface processes. This practice is aligned with a variety of NAEP grade 12 objectives across all five mathematics content areas. Objectives related to various kinds of numbers (real numbers, including expressions with exponents, fractional powers, logarithms, and very large numbers) and their computations are needed to calculate values for different physical quantities (e.g., forces, energy, or amount of matter) involved in the model. Objectives related to measuring physical quantities involved in developing various models and assigning meaningful units to the measured values are used to develop or revise the models. Objectives related to geometric models are needed to represent different biogeochemical cycles, and vectors are needed to represent physical quantities (force and/or velocity) in the models. Data objectives are needed to support extrapolation from the data as well as to collect information in order to revise the model. Algebra objectives are used to model the relationship between physical quantities. Representing and modeling biogeochemical cycles may require the use of ratios, which is more consistent with NAEP grade 8 objectives.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. (2.4) HS-ESS2-4	Grade 12: Number, Measurement, Geometry, Algebra, Data	The NGSS include using a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. This practice is aligned with number of NAEP grade 12 objectives across all four mathematics content areas. Objectives related to various kinds of numbers (e.g., real numbers, proportions, and percentages; expressions using exponents; fractional powers; logarithms; and very large numbers) and their computations are needed to calculate the amount of energy involved in the model. Measurement objectives related to measuring physical quantities and assigning meaningful units to the measured values are needed to develop the models. Objectives related to geometric models are needed to represent different Earth systems. Data objectives related to representing the information obtained from the model, choosing the best fit line, and extrapolating from the data are also needed. Algebra objectives related to modeling the relationship observed in the data as well as solving equations and inequalities may be required as well.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
3. Planning and carrying out investigations		
Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (3.2) HS-PS1-3 HS-PS3-4 HS-LS1-3 HS-ESS2-5	Grade 8: Number, Measurement Grade 12: Number, Measurement, Geometry, Algebra, Data	The NGSS require planning and conducting an investigation to gather evidence. This practice has performance expectations from all three content areas: physical sciences, life sciences, and Earth and space sciences. Specific examples include the strength of electrical forces between particles, the relationship between electric and magnetic forces, how feedback mechanisms maintain homeostasis, and properties of water and its effects. This practice is aligned with variety of NAEP grade 12 objectives across all five mathematics content areas. Objectives related to various kinds of numbers (e.g., real numbers, including expressions utilizing exponents, fractional powers, logarithms, very large numbers, numbers represented as proportions, and percentages) and their computations are needed to calculate the physical quantities used in the model. Measurement objectives related to measuring physical quantities and assigning meaningful units to the measured values are needed to develop the models. Objectives related to geometric models are needed to represent Earth's surface processes. Data objectives related to representing data, using statistical parameters to understand the data sets, well-designed experiments, and reasoning with data are also needed. Algebra objectives related to modeling the relationship observed in the data as a function as well as solving equations and inequalities may be required as well. Measuring weight, mass, and time may require mathematics that is more consistent with NAEP grade 8 objectives.
4. Analyzing and interpreting data		
Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (4.1) HS-PS2-1 HS-ESS2-2 HS-ESS3-5	Grade 12: Number, Measurement, Algebra, Data	The NGSS require analyzing data to support a claim or prediction. Specific performance expectations include Newton's second law of motion, changes to Earth systems, and the current rate of global or regional climate change. These are aligned with NAEP grade 12 objectives related to various kinds of numbers (e.g., real numbers, very small numbers, or numbers represented as proportions, percentages, or rates); expressions using exponents, fractional powers, or logarithms; and their computations. In addition, using measuring units and their accuracy; representing two-dimensional figures algebraically; representing data in charts, graphs, and tables; using statistical parameters to understand the given data sets; reasoning with data; modeling the relationship observed in the data as a function; and solving a system of equations or inequalities may also be needed.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (4.2) HS-LS3-3 HS-LS4-3	Grade 12: Number, Geometry, Algebra, Data	The NGSS require applying concepts of statistics and probability to explain scientific phenomena. The specific performance expectations in life sciences include variation and distribution of expressed traits in a population, and the proportion of organisms with an advantageous heritable trait tend to increase relative to organisms lacking this trait. These are aligned with NAEP grade 12 objectives related to numbers (real numbers, very large numbers, numbers represented as proportions and percentages) and their computations. Moreover, using geometric models to represent genetic traits; representing data in charts, graphs, and tables; using statistical parameters to understand the given data sets, experiments and samples; using probability and reasoning with data; modeling the relationships observed in the data as a function; and solving equations or inequalities may also be required.
5. Using mathematics and computational thinking		
Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. (5.1) HS-PS3-1 HS-LS4-6 HS-ESS3-3	Grade 12: Number, Measurement, Geometry, Algebra, Data	The NGSS require creating or revising a computational model or simulation. This practice has performance expectations from all three content domains: physical sciences, life sciences, and Earth and space sciences. These models include the energy of different components of a system; the impact of human activity on biodiversity; and relationships among natural resources, human populations, and biodiversity. These are aligned with NAEP grade 12 objectives needed in developing models. These are related to numbers (real numbers, including expressions utilizing exponents, fractional powers, logarithms, and very large numbers); using scale drawings; measuring physical quantities; and assigning meaningful units to the measured values. In addition, describing the effect of transformation (reflections, rotations, translations, and dilations) on geometric figures, using coordinate planes, representing two-dimensional figures algebraically, and solving equations or inequalities may be needed. In data, representing data in tables, charts, graphs, and spreadsheets appropriately and effectively; using summary statistics for center tendency and spread to understand a distribution; using probability; reasoning with data; recognizing patterns in the data, including progressions (arithmetic and geometric); and modeling relationships observed in the data as functions (linear, quadratic, exponential, or trigonometric) may also be required.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. (5.2) HS-PS1-7 HS-PS2-2 HS-PS2-4 HS-PS4-1 HS-LS2-1 HS-LS2-2 HS-LS2-4 HS-ESS1-4 HS-ESS3-6 HS-ETS1-4	Grade 12: Number, Measurement, Geometry, Algebra, Data	The NGSS include a performance expectation in engineering design involving the use of computer simulation to model the impact of proposed solutions to complex real-world problems with criteria, constraints, and interactions within and between systems (the specific mathematics required will depend on the particular science context and design problem to be solved). In addition, performance expectations from all three content areas are included that apply this practice. Specific examples include mass is conserved during a chemical reaction; total momentum of a system of objects is conserved; gravitational and electrostatic forces between objects and waves; the carrying capacity of ecosystems; biodiversity in ecosystems; cycling of matter and flow of energy; the motion of orbiting objects in the solar system; and relationships among Earth systems. These performance expectations are aligned with a number of NAEP grade 12 objectives across all five mathematics content areas. The type of mathematics required will depend on the specific problem-solving situation and science principles involved. Objectives related to number operations, estimation, the effect of proportions and scaling on physical attributes (length, areas, and volume), geometric models, vectors, and probability may be needed. In addition, assigning meaningful units to measured values; representing data in tables, charts, graphs, and spreadsheets appropriately and effectively; using summary statistics for center tendency and spread; reasoning with data; recognizing patterns in the data, including progressions (arithmetic and geometric); modeling relationships observed in the data as functions (linear, quadratic, exponential, or trigonometric); and solving equations or inequalities may also be required.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
6. Constructing explanations and designing solutions		
Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (6.2) HS-PS1-2 HS-LS4-2 HS-LS4-4 HS-ESS1-2 HS-ESS3-1	Grade 8: Algebra Grade 12: Number, Measurement, Geometry, Algebra, Data	The NGSS require constructing and revising an explanation based on evidence. This practice has performance expectations in all three content domains: physical sciences, life sciences, and Earth and space sciences. Specific performance expectations involve simple chemical reactions, the process of evolution, natural selection, the Big Bang theory, natural resources, natural hazards, and changes in climate influenced by human activity. These performance expectations are aligned with NAEP grade 12 objectives related to operating with many different kinds of numbers; measuring physical quantities involved in developing various models and assigning meaningful units to the measured values; using scale models and geometric models; applying geometric properties in two- and three-dimensional figures; using vectors to represent physical quantities; representing data in tables, charts, graphs, and spreadsheets appropriately and effectively; using statistical parameters to understand data sets; fitting a trend line on the data; using concepts of experimental design, samples, and probability; reasoning with data; recognizing patterns in the data, including progressions (arithmetic and geometric); modeling relationships observed in the data as functions (linear, quadratic, exponential, or trigonometric); and solving equations or inequalities. The example of simple chemical reactions based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties may require knowledge of geometric patterns that is more consistent with NAEP grade 8 objectives.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (6.3) HS-PS1-5 HS-PS2-3	Grade 8: Measurement Grade 12: Number, Measurement, Geometry, Algebra, Data	The NGSS require applying scientific principles and evidence to provide an explanation or solve a design problem. This practice has two performance expectations in the area of physical sciences. One is about providing an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. The other is to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. These are aligned with NAEP grade 12 objectives related to operating with many different kinds of numbers; measuring physical quantities involved in developing various models and assigning meaningful units to the measured values; using scale models or geometric models; applying geometric properties in two- and three-dimensional figures; and using vectors to represent physical quantities. Objectives needed in data include representing data in tables, charts, graphs, and spreadsheets appropriately and effectively; using statistical parameters to understand data sets; fitting a trend line to data; reasoning with data; recognizing patterns in the data, including progressions (arithmetic and geometric); and modeling relationships observed in the data as functions (linear, quadratic, exponential, or trigonometric). Solving equations or inequalities is also needed. Designing, evaluating, and refining a device may require knowledge of the measurement of physical attributes that is more consistent with NAEP grade 8 objectives.
Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (6.4) HS-ESS1-6	Grade 12: Number, Measurement, Algebra, Data	The NGSS include applying scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. This is aligned with NAEP grade 12 objectives related to operating with many different kinds of numbers; measuring physical quantities involved in developing various models and assigning meaningful units to the measured values; using scale models; representing data in tables, charts, graphs, and spreadsheets appropriately and effectively; using statistical parameters to understand a data set; fitting a trend line on the data; reasoning with data; recognizing patterns in the data, including progressions (arithmetic and geometric); modeling relationships observed in the data as functions (linear, quadratic, exponential, or trigonometric); and solving equations or inequalities.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (6.5) HS-PS1-6 HS-PS3-3 HS-LS2-7 HS-ESS3-4 HS-ETS1-2 HS-ETS1-3	Grade 12: Number, Measurement, Geometry, Algebra, Data	The NGSS include performance expectations in engineering design for designing and evaluating a solution to a complex real-world problem (the specific mathematics required will depend on the particular science context and design problem to be solved). In addition, performance expectations from all three content areas are included that apply this practice. Specific examples include chemical systems, conversion of one form of energy into another, reducing the impacts of human activities on the environment, biodiversity, and natural systems. This performance expectation is aligned with NAEP grade 12 objectives related to various kinds of numbers (real numbers, including expressions utilizing exponents, fractional powers, logarithms, very large numbers, and numbers represented as proportions and percentages), factors and multiples, estimation, the effect of proportions and scaling on physical attributes, accuracy and size of measuring units, and problems involving indirect measurement. In addition, describing the effect of simple transformation (reflection, rotation, translation, and dilation) on two-dimensional figures; using scale drawings or geometric models; using geometric properties (Pythagorean theorem, congruency, similarity, parallelism, perpendicularity, and angles formed by a transversal); representing data in tables, charts, graphs, and spreadsheets appropriately and effectively; using statistical parameters to understand data sets; fitting a trend line to the data; using concepts of samples and probability; reasoning with data; recognizing patterns in the data, including progressions (arithmetic and geometric); modeling relationships observed in the data as functions (linear, quadratic, exponential, or trigonometric); and solving equations or inequalities may also be required.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
7. Engaging in argument from evidence		
Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (7.2) HS-PS4-3 HS-LS2-6 HS-LS4-5 HS-ESS1-5	Grade 12: Number, Measurement, Geometry, Algebra, Data	The NGSS require evaluating the claims, evidence, and reasoning behind explanations or solutions. This practice has performance expectation across all three content domains: physical sciences, life sciences, and Earth and space sciences. Specific examples include the electromagnetic radiation wave versus the particle model, complex interactions in ecosystems, how changes in environmental conditions may result in the emergence or extinction of some species, and the theory of plate tectonics to explain the ages of crustal rocks. This performance expectation is aligned with NAEP grade 12 objectives related to operating with different kinds of numbers, factors and multiples, estimation, the effect of proportions and scaling on physical attributes, the accuracy and size of measuring units, problems involving indirect measurement, and vectors. In addition, describing the effect of simple transformations (reflection, rotation, translation, and dilation) on two-dimensional figures; using scale drawings or geometric models; using geometric properties (Pythagorean theorem, congruency, similarity, parallelism, perpendicularity, and angles formed by a transversal); representing data in tables, charts, graphs, and spreadsheets appropriately and effectively; using statistical parameters to understand data sets; fitting a trend line on data; using the concepts of samples and probability; reasoning with data; recognizing patterns in the data, including progressions (arithmetic and geometric); modeling relationships observed in the data as functions (linear, quadratic, exponential, or trigonometric); and solving equations or inequalities may also be required.
Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. (7.5) HS-LS3-2	Grade 12: Number, Measurement, Algebra, Data	The NGSS include a performance expectation in life sciences on making and defending a claim based on evidence that inheritable genetic variations may result from new genetic combinations, errors occurring during replication, and/or mutations. This performance expectation is aligned with NAEP grade 12 objectives related to operating with many different kinds of numbers; knowing the effects of proportions and scaling on physical attributes; knowing the effects of accuracy and size of measuring units; representing data in tables, charts, graphs, and spreadsheets appropriately and effectively; using statistical parameters to understand data sets using the concepts of probability; reasoning with data; recognizing patterns in the data, including progressions (arithmetic and geometric); modeling relationships observed in the data as functions (linear, quadratic, exponential, or trigonometric); and solving equations or inequalities.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations). (7.6) HS-ESS3-2	Grade 12: Number, Measurement, Algebra, Data	The NGSS include a performance expectation in Earth and space sciences on evaluating competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. This performance expectation is aligned with NAEP grade 12 objectives related to operating with many different kinds of numbers; knowing the effect of proportions and scaling on physical attributes; knowing the effects of accuracy and size of measuring units; representing data in tables, charts, graphs, and spreadsheets appropriately and effectively; using statistical parameters to understand data sets; using the concepts of probability; reasoning with data; recognizing patterns in the data, including progressions (arithmetic and geometric); modeling relationships observed in the data as functions (linear, quadratic, exponential, or trigonometric); and solving equations or inequalities.
8. Obtaining, evaluating, and communicating information		
Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. (8.4) HS-PS4-4	Grade 12: Number, Measurement, Algebra, Data	The NGSS include evaluating the validity and reliability of claims in published materials about the effects that different frequencies of electromagnetic radiation have when absorbed by matter. This performance expectation is aligned with NAEP grade 12 objectives related to using a variety of numbers and computing these numbers; knowing the accuracy and size of measuring units; representing data in tables, charts, graphs, and spreadsheets appropriately and effectively; using statistical parameters to understand data sets; fitting a trend line to data; using the concepts of samples and probability; reasoning with data; recognizing patterns in the data, including progressions (arithmetic and geometric); modeling relationships observed in the data as functions (linear, quadratic, exponential, or trigonometric); and solving equations or inequalities.

NGSS Mathematics-Related Practices and Performance Expectations	Alignment with NAEP Mathematics Framework Objectives	Summary Statement
Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). (8.5) HS-PS2-6 HS-LS4-1 HS-ESS1-3	Grade 12: Number, Measurement, Geometry, Algebra, Data	The NGSS require communicating scientific and technical information in multiple formats. This practice has performance expectations in all three science content domains: physical sciences, life sciences, and Earth and space sciences. Specific examples include molecular-level structure designed materials, the end of a star's life cycle, and biological evolution. These performance expectations are aligned with NAEP grade 12 objectives related to various kinds of numbers (real numbers, including expressions using exponents, fractional powers, logarithms, very large numbers, and numbers represented as proportions and percentages), the accuracy and size of measuring units, and geometric models. Moreover, analyzing three-dimensional figures; describing conic sections; representing data in tables, charts, graphs, and spreadsheets appropriately and effectively; using statistical parameters to understand data sets; reasoning with data; recognizing patterns in the data, including progressions (arithmetic and geometric); modeling relationships observed in the data as functions (linear, quadratic, exponential, or trigonometric); and solving equations or inequalities may also be needed.