Washington Comprehensive Assessment of Science

Test Design & Item Specifications

High School

Washington Office of Superintendent of
PUBLIC INSTRUCTION

Developed by OSPI in collaboration with WestEd

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Purpose Statement

The purpose of the Washington Comprehensive Assessment of Science (WCAS) is to measure the level of science proficiency that Washington students have achieved based on the *Washington State 2013 K–12 Science Learning Standards*. The standards are the *Next Generation Science Standards* (NGSS) and are organized into four domains: Physical Sciences; Life Sciences; Earth and Space Sciences; and Engineering, Technology, and the Applications of Science. Each domain has three-dimensional performance expectations, which integrate science and engineering practices, disciplinary core ideas, and crosscutting concepts. The assessments were first administered in grades 5, 8, and 11 for federal and state accountability purposes in spring 2018.

This item specifications document describes how the item clusters (stimuli and items) and standalone items for the WCAS assessments are developed to assess the NGSS (referred to as “the standards” in the remainder of this document) and includes the second publicly released drafts of the item specifications for the WCAS.

The item specifications are based on the Performance Expectations (PEs) in the standards. The item specification for an individual PE describes how students can demonstrate understanding of the PE on the WCAS. The item specifications are updated annually based on input from Washington educators. Each draft will be accompanied by a modifications log that is updated at each subsequent publication.

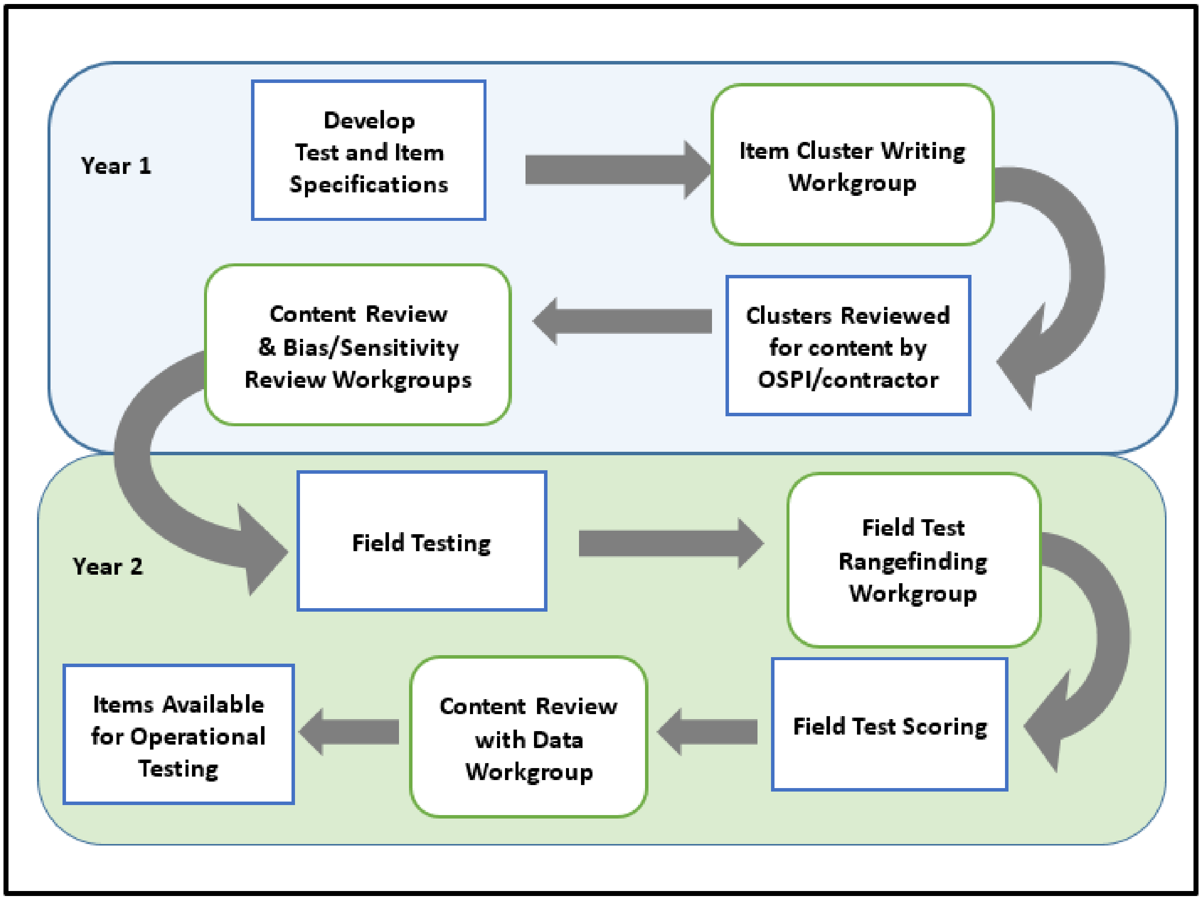
Assessment Development Cycle

The WCAS is written by trained science educators from Washington. Each item cluster and standalone item is planned by the Office of Superintendent of Public Instruction (OSPI) Science Assessment Development Team in conjunction with an educational assessment contractor and then written, reviewed, and revised by educators during an item cluster writing workshop. From there, the development process involves formal reviews with science educators for all clusters and standalone items and for the scoring criteria in the rubrics of technology-enhanced and short-answer items. The development process assures the assessment contains items that meet the following criteria:

- Include authentic stimuli describing scientific phenomena that are grade-level appropriate
- Achieve tight alignment to a specified two- or three-dimensional item specification
- Provide a valid measure of a specified science learning standard
- Include item scoring rubrics that can be validly applied
- Include technology-enhanced and short-answer items that can be reliably scored

The Science Assessment Development Cycle flowchart summarizes the two-year process of review and field testing that precedes clusters and standalone items being used on an operational test.

Science Assessment Development Cycle



OSPI solicits critical input from Washington educators by means of four key workgroups each year:

In the **Item Cluster Writing Workgroup**, teams of two to three educators write stimuli, items, and rubrics designed to validly measure student understanding of the standards.

In the **Content Review Workgroup**, educators review the products of the item cluster writing workgroup to ensure that every stimulus, item, and rubric is scientifically accurate and gathers appropriate evidence about student understanding and application of the standards. At the same time, a separate committee of community members reviews the items and stimuli for any bias or sensitivity issues.

In the **Field Test Rangefinding Workgroup**, educators look at a range of student responses to short answer items and decide how to score each response. This educator workgroup refines scoring rubrics and produces the materials that are used to score the field test items.

In the **Content Review with Data Workgroup**, educators use item performance data, as well as participants' science content knowledge, to decide whether the item should become available for operational testing.

Universal Design

Each phase of the test development process reflects the integration of Universal Design principles with sound measurement theory, current research, and best practices in assessment. These practices result in assessments that are valid, reliable, fair, free from bias, and accessible to all students, including English language learners and students with disabilities.

Universal Design provides a framework for maximizing student participation in an assessment and for providing all students with an opportunity to truly demonstrate what they know and are able to do. The National Center on Educational Outcomes has identified seven elements of universally designed assessments: inclusive assessment population; precisely defined constructs; accessible, non-biased items; amenability to accommodations; simple, clear, and intuitive instructions and procedures; maximum readability and comprehensibility; and maximum legibility (Thompson, Johnstone, Anderson, & Miller, 2005).

Structure of the Test

The WCAS is composed of item clusters and standalone items aligned to the PEs. Advisory groups composed of national education experts, science assessment experts, and science educators recommend the item cluster structure for large-scale assessment of the standards because item clusters involve significant interaction of students with stimulus materials leading to a demonstration of the students' application of knowledge and skills. Standalone items increase the PE coverage that can be achieved in a single test administration.

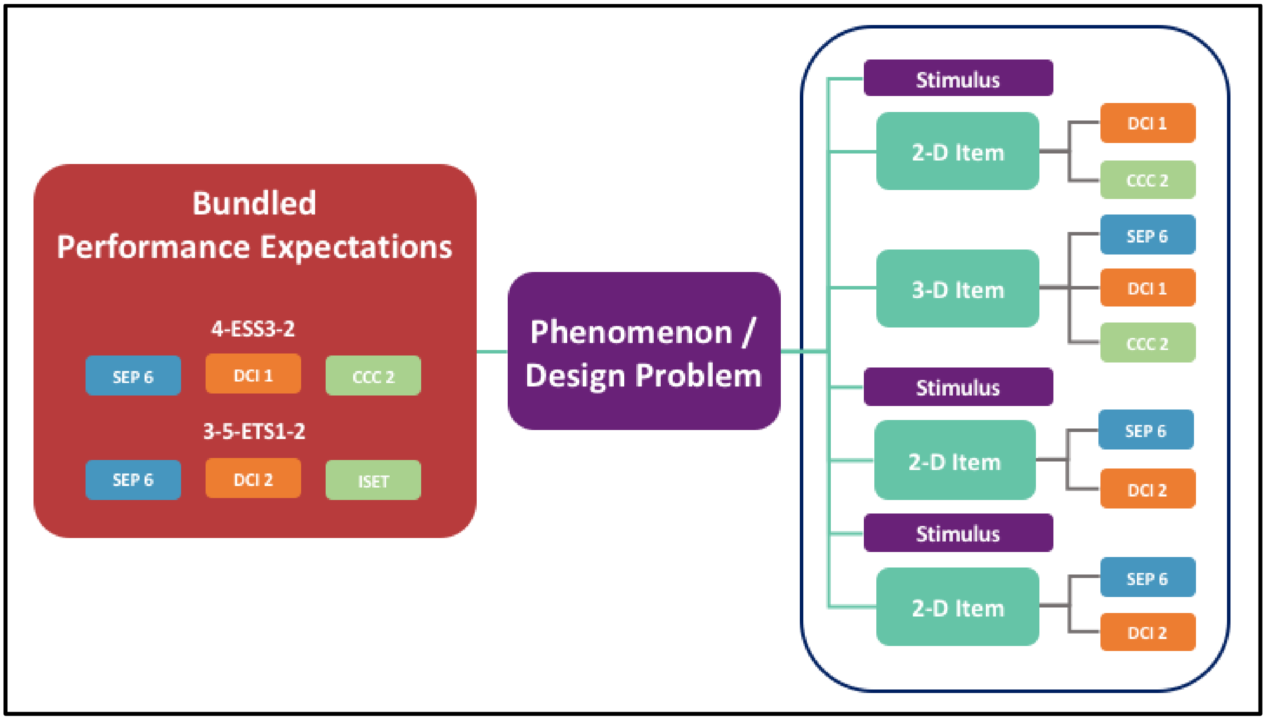
Item Clusters

Item clusters that assess a PE bundle make up the core of the WCAS. A PE bundle is generally two or three related PEs that are used to explain or make sense of a scientific phenomenon or a design problem. A phenomenon gives an item cluster conceptual coherence. The items within an item cluster are interconnected and focused on the given phenomenon. Items are also structured to support a student's progression through the cluster.

Students must make sense of the phenomenon for an item cluster by using the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) represented in the PE bundle. PE bundles are often within a single domain but may include PEs from different domains. PE bundles sometimes share a similar practice or crosscutting concept or may include multiple practices or crosscutting concepts. Each item within the cluster aligns to two or three dimensions (2-D, 3-D) from one or more of the PEs in the bundle, and there is at least one item in the cluster that aligns to all three dimensions of each PE in the bundle. Achieving as full coverage as possible requires developing items that target a variety of the dimensions represented in the PE bundle. In all cases, item clusters achieve full coverage of the dimensions of each PE within a PE bundle.

The Sample Item Cluster Map shows how the items in a sample cluster work together to achieve full coverage of the dimensions in a two-PE bundle.

Sample Item Cluster Map



Standalone Items

A standalone item is a focused measurement tool that uses a single item to address two or three dimensions of one PE.

Online Test Delivery

The WCAS is delivered online using the same platform as the Smarter Balanced ELA and Mathematics assessments. Students should be familiar with most of the online features of the WCAS; however, there are a few unique features that support efficient and reliable delivery of the clusters and standalone items.

Collapsible Stimuli

The WCAS has some item clusters that include more than one stimulus. Each stimulus is delivered along with the items most closely associated to that stimulus. Once a stimulus is presented, it is available to the student throughout the cluster. To minimize vertical scrolling and the need to move back to previous screens within a cluster, a stimulus is collapsed once the next stimulus is provided. A +/- icon in the heading of a collapsed stimulus section allows the stimulus to be hidden from view or expanded to suit a student’s current need.

Locking Items

WCAS clusters include some locking items in which the student cannot change their answer once they have moved to a different item. A padlock icon next to the item number alerts students that they are answering a locking item. When they start to move on from the item, an “attention” box warns the student that they will not be able to change their answer once they move on. The student can either return to the item or move on and lock in their answer.

Locking items allow the student to be updated with correct information in subsequent items or stimuli. In addition, locking items help to limit item interaction effects or clueing between items in a cluster.

Students can return and view an item that has been locked. The student will see their answer, but they cannot change their answer.

Animation

In addition to diagrams and graphics, the online platform supports the use of animations in stimuli. The animations provide additional scaffolding for the student.

Screen Display

Item clusters are displayed with a stimulus pane and an item pane on the same screen. The stimulus occupies 40% of the screen, while the item occupies 60% of the screen. However, by clicking expansion arrows, a student can expand either pane to a width of 90% of the screen. Standalone items are displayed on the entire width of the screen.

Color

WCAS graphics are developed and delivered in color. An educational assessment contractor's graphics team evaluates the text and colors in each graphic using standard tools (e.g., Colour Contrast Analyser (CCA), Sim Daltonism) to ensure the graphic's content is discernible for the widest range of viewers, including those with common types of colorblindness. In the graphic team's use of the tool to determine acceptable color contrast, they consider indicators defined in the Web Content Accessibility Guidelines (WCAG 2.1), which were adopted by the federal government for compliance to Section 508 of the Rehabilitation Act (29 U.S.C. § 794d). Information about supports and/or accommodations for students with visual impairments can be found in the Guidelines on Tools, Supports, & Accommodations, which can be downloaded from the Washington Comprehensive Assessment Program (WCAP) Portal.

Item Types

The WCAS include several item types. Collectively, these item types enable measurement of understanding and core competencies in ways that support student engagement. The majority of the item types are represented on the WCAS Training Tests, which are accessed on the WCAP Portal.

Edit Task Inline Choice (ETC)

- Students select words, numbers, or phrases from drop-down lists to complete a statement.
- The number of drop-down lists in an item is typically between two and four.
- The length of options in a drop-down list is typically one to four words.
- A drop-down list can be part of a table.

Grid Interaction (GI)

- Drag and drop
    - Students place arrows, symbols, labels, or other graphical elements on a background graphic.
    - The elements are designated as refreshable (able to be used multiple times) or non-refreshable (able to be used only one time).
- Hot Spot
    - Students construct simple graphs or select a region on a graphic.

Hot Text (HT)

- Students move statements into an ordered sequence.
- The statements are designated as refreshable (able to be used multiple times) or non-refreshable (able to be used only one time).

Multiple Choice (MC)

- Includes a question, or a statement followed by a question.
- The question presents a clear indication of what is required so students know what to do before looking at the answer choices.
- Students typically select from four options (one correct answer and three distractors).
- The options are syntactically and semantically parallel.
- The options are arranged in numerical or chronological order or according to length.
- Distractors can reflect common errors, misunderstandings, or other misconceptions.
- Distractors are not partially correct.
- The options “All of the above” and “None of the above” are not used.

Multiple Select (MS)

- Includes a clear direction or includes a statement followed by a clear direction.
- The clear direction indicates how many options a student should select to complete the item (e.g., "Select **two** pieces of evidence that support the student's claim").
- The direction presents a clear indication of what is required so students know what to do before looking at the answer choices.
- Students select from a maximum of eight options that have at least two correct responses.
- There should be at least three more distractors than correct answers.
- The options are syntactically and semantically parallel.
- The options are arranged in numerical or chronological order or according to length.
- Distractors can reflect common errors, misunderstandings, or other misconceptions.
- Distractors are not partially correct.
- The options "All of the above" and "None of the above" are not used.

Short Answer (SA)

- Students write a response based on a specific task statement.
- Directions give clear indications of the response required of students.
- When appropriate, bullets after phrases like "In your description, be sure to:" provide extra details to assist students in writing a complete response.
- A response that requires multiple parts may be scaffolded with response boxes to draw attention to the parts.
- Any SA item that requires the students to use information from a stimulus specifically prompts for the information, such as "Use data from the table to …" or "Support your answer with information from the chart."
- Students type text and/or numbers into a response box using the keyboard. SA items are scored by human readers using a scoring rubric.

Simulation (SIM)

- Students use a simulation to control an investigation and/or generate data.
- Simulations can vary in their interaction, design, and scoring.
- The data can be scored directly or used to answer related questions, or both.

Table Input (TI)

- Students complete a table by typing numeric responses into the cells of the table using the keyboard.
- Positive values, negative values, and decimal points are accepted.

Table Match (MI)

- Students check boxes within the cells of a table to make identifications, classifications, or predictions.
- Students are informed when a row or column may be checked once, more than once, or not at all.

Scoring Rubric Development Guidelines

- An item-specific scoring rubric is developed for each ETC, GI, HT, SIM, TI, MI, and SA during the writing of the item.
- Scoring rubrics do not consider conventions of writing (complete sentences, usage/grammar, spelling, capitalization, punctuation, and paragraphing).
- Scoring rubrics are edited during field test rangefinding and rubric validation based on student responses.
- Scoring rubrics may be edited during operational rangefinding based on student responses.

Multipart Items

Some items are divided into multiple parts. Typically, this includes two parts (part A and part B). Item parts are mutually reinforcing and strengthen alignment to a PE.

Multipart items can use different types of interaction in each part (e.g., an MC followed by an ETC). One example of this approach is an item that asks a student to evaluate a claim in part A, and then in part B asks the student to identify how a particular trend in data or piece of evidence supports their evaluation of that claim.

Multipart items are scored collectively with each part contributing toward a single point, or separately with each part earning a single point.

When assessed in an item that does not have multiple parts, the following score points are typically assigned for each item type:

- ETC, GI, HT, MC, MS, SIM, TI, and MI items are worth 1 point.
- SA items are worth 1 or 2 points.

Test Design

Operational Test Form

Each operational test form contains the same items in a given year. This is known as a "fixed-form test," which is unlike the "adaptive" Smarter Balanced test. Approximately 33% of the points of the fixed-form test are anchoring (linking) items with established item calibrations from previous years.

The operational component of the WCAS counts toward a student's score and is composed of six clusters and six to twelve standalone items.

In addition:

- One PE from domain (ESS, PS, LS, and ETS) is included in at least one item cluster.
- A minimum of three different SEPs are included across the clusters.
- A minimum of three different CCCs are included across the clusters.
- Standalone items increase DCI, SEP, and CCC coverage.

Field Test Items

Operational test forms contain embedded field test items, which are either a set of items associated with a cluster, a group of standalone items, or a combination of one cluster and one or more standalone items. Several clusters and standalone items are field tested in a given administration. The field test items do not contribute to the student's score.

Testing Times

The WCAS is intended to be administered online in one to three sessions. The approximate 150-minute administration time includes 30 minutes for giving directions and distributing materials, 105 minutes for the operational form, and 15 minutes for the embedded field test. Contact your district testing coordinator for further information on the specific test schedule for your district or building.

Online Calculator

A calculator is embedded in the online platform for all items in the WCAS. Students should be familiar with the functionality of the calculator prior to using it on the assessment. The calculator is available online and as an app for practice. In grade 5, students use a basic four-function calculator. In grades 8 and high school, students use a scientific calculator.

Periodic Table

A periodic table is embedded in the online platform for all items in the WCAS for grade 8 and high school. A printable version of the periodic table can be downloaded from the WCAP Portal for classroom use.

Tools, Supports, and Accommodations

The WCAS may be taken with or without tools, supports, or accommodations. Tools are available to all students and can be used at the student's discretion. Supports are available to English language learners and any student with a need identified by an educator. Accommodations are available for students who receive special education services with a documented need noted in an IEP or 504 plan. More information is available in the Guidelines on Tools, Supports, & Accommodations which can be downloaded from the WCAP Portal.

Test Blueprint

The total number of points for the WCAS in high school is 45 points. The point percentages of the WCAS reflect the percentages of the PEs per domain within the standards.

The Engineering, Technology, and Applications of Science (ETS) domain is not represented by a separate item cluster, but is bundled in at least one item cluster with one or more PEs from the Physical Sciences (PS), Life Sciences (LS), or Earth and Space Sciences (ESS) domain. ETS points are not specified, and ETS PEs were not included when calculating the percentages in Table 1.

Table 1 specifies the percentage and point ranges of the WCAS in reference to the reporting claims.

Table 1

Reporting Area	Percentage of PEs per Science Domain in the Standards	Percentage Range for the WCAS per Science Domain	Score Point Range for the WCAS per Science Domain
Practices and Crosscutting Concepts in Physical Sciences	36%	31–41%	14–18
Practices and Crosscutting Concepts in Life Sciences	36%	31–41%	14–18
Practices and Crosscutting Concepts in Earth and Space Sciences	28%	23–33%	11–15

Washington Standards Overview

The WCAS is designed to align to the standards in a way that honors the original intent of the document *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (2012) and supports Washington educators in their interpretation of assessment results, instructional design, and classroom practice. This section discusses the structure and usage of PEs as a guiding framework for the development of the WCAS item specifications.

Performance Expectations

The standards are organized into Performance Expectations (PEs). Each PE provides a statement of what students should be able to do by the end of instruction. There are 45 PEs for grades 3–5, 59 PEs for middle school, and 71 PEs for high school. The PEs are further categorized by grade or grade band (K, 1, 2, 3, 4, 5, MS, HS) and by domain: Physical Sciences (PS); Life Sciences (LS); Earth and Space Sciences (ESS); and Engineering, Technology, and Applications of Science (ETS).

Identifying a PE

Each PE is identified by a three-part PE code. The first set of letters or numbers indicates the grade level (or grade band) of the PE (e.g., HS for high school). The middle set of letters and numbers in a PE code refers to an overarching organizing concept that is developed across grades. For example, in MS-ESS1-2, “ESS1” refers to “Earth’s Place in the Universe.”

Finding Related PEs

Searching the NGSS website for an organizing concept results in a complete list of associated PEs at the given grade level. For example, searching the website for MS-ESS1 results in a list of associated PEs at the middle school level (MS-ESS1-1 through MS-ESS1-4). Substituting another grade level for “MS” results in a complete list of standards related to “Earth’s Place in the Universe” for any other grade level. This strategy is helpful for understanding where a particular PE fits in a learning progression, and it can provide insight into the assessable boundaries of a PE.

PE Structure

Each PE starts with the PE statement, which is a brief synopsis of the performance the PE is meant to address. Each PE statement incorporates the three dimensions of the NGSS framework: one or more Science and Engineering Practices (SEPs), one or more Disciplinary Core Ideas (DCIs), and one or more Crosscutting Concepts (CCCs). The PE statement can provide some insight as to how students are expected to utilize the SEPs, DCIs, and CCCs together to achieve the PE.

Clarification Statements and Assessment Boundaries

The PE statement may be followed by a clarification statement and/or an assessment boundary. When present, the clarification statement supplies examples or additional clarification to the PE. The assessment boundaries are meant to specify limits for large-scale assessment of a PE. They are **not** meant to limit what can or should be taught or how it is taught. The main function of an assessment boundary statement is to provide guidance to assessment developers.

Dimensions—SEPs, DCIs, and CCCs

Science and Engineering Practices

The standards include a total of eight SEPs that develop across grade levels and grade bands:

1. Asking Questions and Defining Problems
2. Developing and Using Models
3. Planning and Carrying Out Investigations
4. Analyzing and Interpreting Data
5. Using Mathematical and Computational Thinking
6. Constructing Explanations and Designing Solutions
7. Engaging in Argument from Evidence
8. Obtaining, Evaluating, and Communicating Information

For the standards and the WCAS Item Specifications, the SEP statement is presented in the leftmost column inside a blue box. Each SEP statement contains a particular skill or practice from a particular grade level, as determined by the PE. Bulleted text under the grade-level description of the SEP presents a subskill associated with the specific PE. Additional details on the subskills and their progressions across grade bands are located in NGSS Appendix F.

Disciplinary Core Ideas

Science knowledge is represented as a collection of disciplinary core ideas, which have been explicitly developed in grade-level progressions. For the standards and the WCAS Item Specifications, the DCI statement is presented in the middle column inside an orange box. The number of DCIs is intentionally limited, so as to allow deeper exploration and eventual proficiency of key concepts as students broaden and deepen their understanding of science. The sum total of all DCIs is not meant to be an exhaustive list of all topics that should be taught in a science classroom. Rather, DCIs provide for links among classroom lesson or activity topics at a high level. DCIs are broken up into several groups within four domains: Physical Sciences (PS), Life Sciences (LS), Earth and Space Sciences (ESS), and Engineering, Technology, and Applications of Science (ETS).

Each DCI statement contains key ideas appropriate to a particular grade level, as determined by the PE. Bulleted text under the grade-level description of the DCI presents ideas and understandings associated with the specific DCI. Additional details on these ideas and understandings and their progressions across grade bands are located in NGSS Appendix E.

Crosscutting Concepts

The standards contain seven CCCs that progress throughout each grade level and grade band. The seven CCCs are:

1. Patterns
2. Cause and Effect
3. Scale, Proportion, and Quantity
4. Systems and System Models
5. Energy and Matter
6. Structure and Function
7. Stability and Change

For the standards and the WCAS Item Specifications, the CCC statement is presented in the rightmost column, inside a green box. Bulleted text under the grade-level description of the CCC presents sub-concepts associated with the specific PE. Additional details on these sub-concepts and their progressions across grade bands are located in NGSS Appendix G.

NGSS Progressions Appendices

When working to establish learning progressions or continuity and growth of skills across grade levels, educators will find value in the NGSS progressions appendices (see the "Resources" section). Organized by dimension (SEP, DCI, and CCC), the appendices present detailed learning progressions and comparisons of various skills and competencies across grade levels.

The WCAS Item Specifications use the NGSS progressions appendices in unpacking PE dimension statements to reveal and incorporate elements from a given learning progression. For example, consider a grade 4 PE that lists Planning and Carrying Out Investigations as its SEP dimension and has bulleted text that focuses on making observations. According to the NGSS learning progressions, making observations may be expanded within grade 4 to also include elements of planning, prediction, or evaluations of a fair test. Therefore, from an assessment perspective, items written using these linked subskills still align to the SEP.

Evidence Statements

The NGSS evidence statements were designed to support a granular analysis of proficiency with specific PEs, via an explicit articulation of how students can use SEPs to demonstrate their understanding of DCIs through the lens of the CCCs. They do this by clarifying several important details related to the three dimensions:

- How the three dimensions can be assessed together, rather than in independent units
- The underlying knowledge required to develop each DCI
- The detailed approaches to application of the SEP
- How CCCs might be used to deepen content understanding and practice-driven learning

The NGSS evidence statements informed the development of the WCAS Item Specifications.

Resources

Resource	Description
K–12 Framework	Provides information about the foundational principles that were used to develop the NGSS.
SAIC Assessment Framework	Provides options and rationales for development of high-quality, NGSS-aligned summative assessment items.
SAIC Prototype Item Cluster	Demonstrates a three-dimensional NGSS-aligned item cluster using a variety of stimuli and innovative item types.
Developing Assessments for the Next Generation Science Standards	Provides guidance on an approach to science assessment that supports the vision of the NGSS.
NGSS Appendix E	Includes tables showing the **DCI** progressions by grade level.
NGSS Appendix F	Includes tables showing the **SEP** progressions by grade level.
NGSS Appendix G	Includes tables showing the **CCC** progressions by grade level.
NGSS Evidence Statements	Provides additional detail on what students should know and be able to do based on performance expectations.

References

Council of Chief State School Officers (CCSSO). (2015). *Science Assessment Item Collaborative (SAIC) Assessment Framework*.: Council of Chief State School Officers.

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WCAS Item Specifications

Introduction

The science assessment team at OSPI worked with assessment research and development partners to create assessment item specifications that support multidimensional item development and assist teachers in their interpretation of WCAS assessment data. The following two pages present a sample of one such item specification.

The WCAS Item Specifications are a guiding framework that is built to evolve and change; OSPI revises them as needed, in collaboration with teachers and other stakeholders. While the item specifications are not intended to dictate curricula in any way, examples of science topics or contexts within the scope of the PE may occasionally be provided in the details and clarifications section. Such examples are noted in parenthetical remarks after a particular clarification, and denoted with the convention "e.g."

The first page of a WCAS item specification consolidates key information under the same PE code used by the corresponding standard in the NGSS. It also directs users to pertinent pages in the *K–12 Framework* and the NGSS progressions appendices for each dimension (SEP, DCI, or CCC). The first page also presents any clarification statements or assessment boundaries associated with the PE. Items on the grade 11 WCAS use language targeted to the previous grade or lower reading level with the exception of the expected science terms. A list of expected DCI, SEP, and CCC vocabulary is included at the end of this document.

The second page of each item specification presents four alignment codes for the PE. These codes identify the various combinations of PE dimensions that can be measured using a multidimensional item. Additionally, each item specification includes a list of details and clarifications that help unpack the elements used to determine item alignment.

For example, when using the WCAS Item Specifications, an item with an alignment code of 4-LS1-1.2 indicates that the item aligns to both the SEP and DCI dimensions of the PE 4-LS1-1. The item specification suggests that this type of item involves making observations of specific types of evidence related to the DCI. The Details and Clarifications section lists examples of observations that are permissible under this PE, as well as the forms of evidence that are within the bounds of the PE.

As stated earlier in this document, item specifications are updated annually based on input from Washington educators. Each publication of the updated item specifications includes a modifications log.

Physical Sciences

Disciplinary Core Ideas:

- PS1 Matter and Its Interactions
- PS2 Motion and Stability: Forces and Interactions
- PS3 Energy
- PS4 Waves and Their Applications in Technologies for Information Transfer

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Use a model to predict the relationships between systems or between components of a system.	**PS1.A: Structure and Properties of Matter** • Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. • The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 56–59	pp. 106–109	pp. 85–87
NGSS Appendices	Appendix F p. 6	Appendix E p. 7	Appendix G pp. 3–5
Clarification Statement	Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.		
Assessment Boundary	Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS1-1.1	SEP-DCI-CCC	**Use** the **periodic table** as a **model** to **predict** the **relative properties** of **elements** based on the **patterns** of **valence electrons**.
HS-PS1-1.2	SEP-DCI	**Use** the **periodic table** as a **model** to describe the **properties** of **elements**.
HS-PS1-1.3	DCI-CCC	Connect the relative **properties** of **elements** to **patterns** of **valence electrons** from the periodic table.
HS-PS1-1.4	SEP-CCC	**Develop** and/or **use** patterns in a **model** to make predictions.

Details and Clarifications

- **Use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems.
  - using a given complete or partial model to make predictions and/or describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- Components of the **periodic table** as a model may include, but are NOT limited to:
  - elements having a positively charged nucleus with both protons and neutrons, surrounded by negatively charged electrons
  - elements in rows having increasing numbers of protons
  - elements in columns having the same number of valence electrons

- Examples of **predicting** the **relative properties** of **elements** based on **patterns** of **valence electrons** may include, but are NOT limited to:
  - predicting the numbers and/or types of bonds formed by an element and/or between elements
  - predicting the charges of stable ions that form from atoms in a group
  - predicting the reactivity and/or electronegativity of atoms in a group and/or in a row
  - predicting the relative sizes of atoms in a group and/or in a row

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, and 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.</td><td>PS1.A: Structure and Properties of Matter
• The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

PS1.B: Chemical Reactions
• The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 67–71</td><td>pp. 106–109
pp. 109–111</td><td>pp. 85–87</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 11–12</td><td>Appendix E
p. 7</td><td>Appendix G
pp. 3–5</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment is limited to chemical reactions involving main group elements and combustion reactions.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-PS1-2.1	SEP-DCI-CCC	**Construct** and/or **revise** an **explanation** based on **evidence** for the outcome of a **chemical reaction** based on **patterns** in the **periodic table**.
HS-PS1-2.2	SEP-DCI	**Construct** and/or **revise** an **explanation** based on **evidence** for the outcome of a **chemical reaction** based on knowledge of the **periodic table**.
HS-PS1-2.3	DCI-CCC	Connect **patterns** in the periodic table and/or **patterns** of **chemical properties** to the outcome of a **chemical reaction**.
HS-PS1-2.4	SEP-CCC	**Construct** and/or **revise** an **explanation** based on patterns in a system.

Details and Clarifications

- **Construct** and/or **revise** an **explanation** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- **Types of evidence** may include, but are NOT limited to:
  - chemical formulas
  - number of valence electrons in elements
  - number and/or types of atoms in reactants and/or products
  - number and/or types of bonds in reactants and/or products
  - relative electronegativity of elements in reactants and/or products
  - chemical properties of reactants and/or products, based on positions in the periodic table

- **Explanations** of **chemical reaction** may include, but are NOT limited to:
  - atoms of each element in reactants and products are conserved
  - the number and/or types of bonds formed is determined by the number of valence electrons and/or the electronegativity of elements
  - a prediction of the type of reaction that occurs (e.g., formation of ionic compounds, combustion of hydrocarbons)

- **Patterns** in the **periodic table** may include, but are NOT limited to:
  - the number of protons for atoms of an element
  - the number of electrons for atoms of an element
  - the reactivity of atoms of an element
  - the number of bonds that atoms of an element form
  - chemical reactions that can be used to infer chemical properties of atoms and/or to predict related reactions among atoms in similar groups in the periodic table

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Planning and Carrying Out Investigations
Planning and carrying out investigations in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.
• 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.</td><td>PS1.A: Structure and Properties of Matter
• The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 59–61</td><td>pp. 106–109
pp. 116–118</td><td>pp. 85–87</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 7–8</td><td>Appendix E
p. 7</td><td>Appendix G
pp. 3–5</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment does not include Raoult’s law calculations of vapor pressure.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-PS1-3.1	SEP-DCI-CCC	**Plan** and/or **conduct** an **investigation** to gather evidence of **patterns** among the structures and/or **properties** of substances at the **bulk scale** and/or the strength of **electrical forces** between **particles**.
HS-PS1-3.2	SEP-DCI	**Plan** and/or **conduct** an **investigation** to gather evidence of the structures and/or **properties** of substances at the **bulk scale** and/or the strength of **electrical forces** between **particles**.
HS-PS1-3.3	DCI-CCC	Connect **patterns** among the structures and/or **properties** of substances at the **bulk scale** and/or the strength of **electrical forces** between **particles**.
HS-PS1-3.4	SEP-CCC	**Plan** and/or **conduct** an **investigation** to produce **evidence** of patterns in a system.

Details and Clarifications

- **Plan** and/or **conduct** an **investigation** is expanded to include:
  - planning for and/or producing data to serve as evidence for developing and/or revising models, supporting an explanation, and/or testing a solution
  - planning for and/or evaluating an investigation to identify possible confounding variables and/or to ensure that variables are controlled
  - determining the type, amount, and/or accuracy of data needed to produce reliable measurements and/or considering limitations on the precision of the data (e.g., number of trials, cost, risk, time)
  - selecting appropriate processes, methods, and/or tools to collect, record, analyze, and/or evaluate data
  - predicting what happens to a dependent variable when an independent variable is manipulated
  - identifying failure points and/or describing performance relative to criteria for success

- Examples of the **properties** of substances at the **bulk scale** may include, but are NOT limited to:
  - melting point
  - boiling point
  - vapor pressure
  - surface tension

- Examples of the strength of **electrical forces** between **particles** may include, but are NOT limited to:
  - relatively large electrical forces between ions in a salt
  - relatively small electrical forces between nonpolar molecules

- Examples of **patterns** may include, but are NOT limited to:
  - liquids with relatively strong intermolecular forces between molecules having relatively high surface tension
  - substances with relatively weak intermolecular forces between molecules having relatively low boiling points
  - the addition of thermal energy to a substance increasing the distance between particles and/or decreasing the attraction between particles that keeps particles close together

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>PS1.A: Structure and Properties of Matter
• A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

PS1.B: Chemical Reactions
• Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.</td><td>Energy and Matter
• Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 56–59</td><td>pp. 106–109
pp. 109–111</td><td>pp. 94–96</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 6</td><td>Appendix E
p. 7</td><td>Appendix G
pp. 8–9</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-PS1-4.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** to illustrate that the **release** or **absorption** of **energy** from a **chemical reaction system** depends upon changes in **total bond energy**.
HS-PS1-4.2	SEP-DCI	**Develop** and/or **use** a **model** to illustrate a **chemical reaction system**.
HS-PS1-4.3	DCI-CCC	Connect the **release** or **absorption** of **energy** from a **chemical reaction system** to changes in **total bond energy**.
HS-PS1-4.4	SEP-CCC	**Develop** and/or **use** a **model** to illustrate changes in energy and/or matter in a system.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- Components of a **chemical reaction system** may include, but are NOT limited to:
  - a chemical reaction and its surroundings
  - reactants, products, and/or atoms involved in a chemical reaction
  - bonds broken during a chemical reaction
  - bonds formed during a chemical reaction
  - energy transfer within a system
  - energy transfer between a system and its surroundings

- Examples of the **release** or **absorption** of **energy** from a **chemical reaction system** depending on changes in **total bond energy** may include, but are NOT limited to:
  - the change in the total bond energy of reactants and products accounting for the net energy change of a system
  - an energy input to a system breaking bonds in reactant molecules
  - the formation of bonds in product molecules releasing energy to a system and/or its surroundings
  - energy transferred between a system and its surroundings balancing the difference between the total bond energy of the products and the total bond energy of the reactants
  - energy transferring between a system and its surroundings by molecular collisions
  - overall energy of a system and its surroundings remaining unchanged during chemical reactions

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.	**PS1.B: Chemical Reactions** • Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 67–71	pp. 109–111	pp. 85–87
NGSS Appendices	Appendix F p. 11	Appendix E p. 7	Appendix G pp. 3–4
Clarification Statement	Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.		
Assessment Boundary	Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS1-5.1	SEP-DCI-CCC	Apply scientific principles and/or evidence from **patterns** to **provide** an **explanation** about the effects of changing the temperature and/or concentration of reacting particles on the rate at which a reaction occurs.
HS-PS1-5.2	SEP-DCI	Apply scientific principles and/or evidence to **provide** an **explanation** about the effects of changing the temperature and/or concentration of reacting particles on the rate at which a reaction occurs.
HS-PS1-5.3	DCI-CCC	Use **patterns** to connect the effects of changing the temperature and/or concentration of reacting particles on the rate at which a reaction occurs.
HS-PS1-5.4	SEP-CCC	Apply scientific principles and/or evidence from patterns to **provide** an **explanation** about a phenomenon.

Details and Clarifications

- Apply scientific principles and/or evidence to **provide** an **explanation** is expanded to:
    - making claims about relationships between dependent and independent variables
    - using valid and/or reliable evidence to construct and/or revise an explanation
    - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
    - using evidence to evaluate how well a solution meets the criteria for success
    - using evidence to evaluate the constraints that may limit the success of a solution
    - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- Types of **patterns** may include, but are NOT limited to:
    - relationships between temperature and reaction rate
    - relationships between reactant concentration and reaction rate
    - relationships between product concentration and reaction rate
    - collisions between molecules that break or form new bonds
    - the rearrangement of atoms into new molecules
    - changes in the bond energy and/or kinetic energy of molecules in a reaction

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**PS1.B: Chemical Reactions** • In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. *(secondary)*	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 67–71	pp. 109–111 pp. 208–210	pp. 98–101
NGSS Appendices	Appendix F pp. 11–12	Appendix E p. 7 Appendix I pp. 1–7	Appendix G pp. 10–11
Clarification Statement	Emphasis is on the application of Le Chatelier’s Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.		
Assessment Boundary	Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS1-6.1	SEP-DCI-CCC	**Design**, **evaluate**, and/or **refine** a chemical **system** by specifying a change in **conditions** that would produce **increased amounts** of **products** at **equilibrium**.
HS-PS1-6.2	SEP-DCI	**Design**, **evaluate**, and/or **refine** a chemical **system** by specifying the **conditions** of the system.
HS-PS1-6.3	DCI-CCC	**Connect** a change in the **conditions** of a **chemical system** to the production of **increased amounts** of **products** at **equilibrium**.
HS-PS1-6.4	SEP-CCC	**Design**, **evaluate**, and/or **refine** a **system** that changes and/or remains stable.

Details and Clarifications

- **Design**, **evaluate**, and/or **refine** a **system** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- Examples of changes in **conditions** that would produce **increased amounts** of **products** at **equilibrium** may include, but are NOT limited to:
  - increasing or decreasing the concentration of a reactant or a product
  - increasing or decreasing the pressure on a system
  - adding thermal energy to or removing thermal energy from a system

- Examples of the **conditions** of a **system** at **equilibrium** may include, but are NOT limited to:
  - the concentrations of reactants and products are constant
  - the rate of the forward reaction equals the rate of the reverse reaction

<table>
<tr><th>Performance Expectation</th><th colspan="3">HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.</th></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
• Use mathematical representations of phenomena to support claims.</td><td>PS1.B: Chemical Reactions
• The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.</td><td>Energy and Matter
• The total amount of energy and matter in closed systems is conserved.

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
• Science assumes the universe is a vast single system in which basic laws are consistent.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 64–67</td><td>pp. 109–111</td><td>pp. 94–96</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 10</td><td>Appendix E
p. 7</td><td>Appendix G
pp. 8–9
Appendix H
p. 6</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students’ use of mathematical thinking and not on memorization and rote application of problem-solving techniques.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment does not include complex chemical reactions.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-PS1-7.1	SEP-DCI-CCC	**Use mathematical representations** to support the claim that **atoms** and/or **mass** are **conserved** during a chemical reaction.
HS-PS1-7.2	SEP-DCI	**Use mathematical representations** to describe **atoms** and/or **mass** during a chemical reaction.
HS-PS1-7.3	DCI-CCC	Connect the **conservation** of matter to **atoms** and/or **mass** during a chemical reaction.
HS-PS1-7.4	SEP-CCC	**Use mathematical representations** to support claims about matter and/or energy.

Details and Clarifications

- **Use mathematical representations** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system.
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations.
  - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems.

- Components of **mathematical representations** may include, but are NOT limited to:
  - quantities of reactants and/or products (e.g., number of atoms, number of moles, mass)
  - molar masses
  - balanced chemical equations

- **Use mathematical representations** to support the claim that **atoms** and/or **mass** are **conserved** during a chemical reaction may include, but is NOT limited to:
  - describing and/or calculating quantities of reactants and/or products
  - using Avogadro’s number to convert between the atomic and macroscopic scales (e.g., moles to mass, moles to molecules)
  - using balanced equations to determine mole ratios between two substances
  - predicting the relative number of atoms of reactants and/or products, given some information
  - predicting the mass of one substance in a chemical reaction, given the masses of all of the other substances in the reaction
  - using given calculations to support a claim about the conservation of matter and/or conversions between the atomic and macroscopic scales

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**PS1.C: Nuclear Processes** • Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.	**Energy and Matter** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 56–59	pp. 111–113	pp. 94–96
NGSS Appendices	Appendix F p. 6	Appendix E p. 7	Appendix G pp. 8–9
Clarification Statement	Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.		
Assessment Boundary	Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS1-8.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** to illustrate **changes** in the **composition** of the **nuclei** of atoms and/or **changes** in **energy** during the processes of **fission**, **fusion**, and/or **radioactive decay**.
HS-PS1-8.2	SEP-DCI	Due to a strong overlap between the DCI and the CCC, items are not coded HS-PS1-8.2.
HS-PS1-8.3	DCI-CCC	Connect **changes** in the **composition** of the **nuclei** of atoms and/or **changes** in **energy** to the processes of **fission**, **fusion**, and/or **radioactive decay**.
HS-PS1-8.4	SEP-CCC	**Develop** and/or **use** a **model** to illustrate changes in energy and/or matter in a system.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- **Models** may include, but are NOT limited to:
  - elements, identified by number of protons
  - numbers of protons and neutrons before and/or after decay
  - the identity of an emitted particle (i.e., alpha, beta, gamma)
  - energy changes for nuclear processes and/or chemical processes

- Examples of illustrating **changes** in the **composition** of **nuclei** and/or **changes** in **energy** during **fission**, **fusion**, and/or **radioactive decay** may include, but are NOT limited to:
  - two nuclei merging to form a new nucleus with a different number of protons than either of the original nuclei
  - a nucleus splitting into parts, each with a smaller number of protons than the original nucleus
  - the number of neutrons plus protons being the same before and after the nuclear process
  - nuclear fusion releasing energy and/or requiring energy to occur
  - nuclear fission releasing energy and/or requiring energy to occur
  - radioactive decay releasing different types of energy (e.g., kinetic energy, electromagnetic radiation) and/or types of particles (e.g., alpha particle, beta particle)

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories and laws provide explanations in science. • Laws are statements or descriptions of the relationships among observable phenomena.	**PS2.A: Forces and Motion** • Newton's second law accurately predicts changes in the motion of macroscopic objects.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 61–63	pp. 114–116	pp. 87–89
NGSS Appendices	Appendix F p. 9 Appendix H p. 5	Appendix E p. 7	Appendix G pp. 5–6
Clarification Statement	Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.		
Assessment Boundary	Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS2-1.1	SEP-DCI-CCC	**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/or its **acceleration**.
HS-PS2-1.2	SEP-DCI	**Analyze data** to support a claim about the **net force** on a macroscopic object, its **mass**, and/or its **acceleration**.
HS-PS2-1.3	DCI-CCC	Use **Newton's second law** of motion to describe the **mathematical relationship** among the **net force** on a macroscopic object, its **mass**, and/or its **acceleration**.
HS-PS2-1.4	SEP-CCC	**Analyze data** to support a **claim** about cause and effect relationships in a system.

Details and Clarifications

- **Analyze data** is expanded to include:
  - organizing and/or interpreting data using tables, graphs, and/or statistical analysis
  - identifying relationships in data using tables and/or graphs
  - identifying limitations (e.g., measurement error, sample selection) in data
  - comparing the consistency in measurements and/or observations in sets of data
  - using analyzed data to support a claim and/or an explanation

- Examples of **Newton's second law** describing **mathematical relationships** among **net force, mass,** and/or **acceleration** may include, but are NOT limited to:
  - a force causing a smaller acceleration on a more massive object than on a less massive object
  - an increase in the net force on an object causing an increase in the acceleration of the object
  - a net force that is not zero causing a change in motion of a given object
  - objects of different mass with the same acceleration experiencing different net forces

Note: The equation F=ma is not provided on the WCAS.

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena to describe explanations.	**PS2.A: Forces and Motion** • Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.	**Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 64–67	pp. 114–116	pp. 91–94
NGSS Appendices	Appendix F p. 10	Appendix E p. 7	Appendix G pp. 7–8
Clarification Statement	Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.		
Assessment Boundary	Assessment is limited to systems of two macroscopic bodies moving in one dimension.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS2-2.1	SEP-DCI-CCC	**Use mathematical representations** to describe that **momentum** is **conserved** when there is no net force on a **system** of two interacting objects.
HS-PS2-2.2	SEP-DCI	**Use mathematical representations** to describe the **momentum** of interacting objects.
HS-PS2-2.3	DCI-CCC	Connect changes in **momentum** to a **system** of two interacting objects.
HS-PS2-2.4	SEP-CCC	**Use mathematical representations** to describe a system.

Details and Clarifications

- **Use mathematical representations** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
  - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems

- **Mathematical representations** may include, but are NOT limited to:
  - the masses, speeds, and/or directions of motion of two interacting objects in a system
  - the momentum of each object in a system, calculated by multiplying the mass and the velocity of the object ($p=mv$)
  - a change in the momentum of each object as a result of an interaction
  - the total momentum of the system

- Evidence that **momentum** is **conserved** within the system may include, but is NOT limited to:
  - calculating, modeling, and/or describing that the total momentum of two interacting objects in a system is constant if there is no net force applied to the system
  - calculating, modeling, and/or describing that a change in the momentum of one interacting object is balanced by a change in the momentum of the other interacting object within a system
  - calculating, modeling, and/or describing that a change in the momentum of a system is balanced by a change in momentum of objects outside the system

- Describing a **system** may include, but is NOT limited to:
  - describing components, boundaries, and/or initial conditions (e.g., initial momentum of each system object)
  - describing forces external to a system

Note: The equation, $p=mv$, is not given on the WCAS.

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.	**PS2.A: Forces and Motion** • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. **ETS1.A: Defining and Delimiting an Engineering Problem** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary)* **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. *(secondary)*	**Cause and Effect** • Systems can be designed to cause a desired effect.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 67–71	pp. 115–116 pp. 204–206 pp. 208–210	pp. 87–89
NGSS Appendices	Appendix F pp. 11–12	Appendix E p. 7 Appendix I pp. 1–7	Appendix G pp. 5–6
Clarification Statement	Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.		
Assessment Boundary	Assessment is limited to qualitative evaluations and/or algebraic manipulations.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS2-3.1	SEP-DCI-CCC	**Apply scientific** and/or **engineering ideas** using **cause** and **effect** relationships to design, evaluate, and/or refine a **device** that **minimizes** the **force** on a macroscopic object during a collision.
HS-PS2-3.2	SEP-DCI	**Apply scientific** and/or **engineering ideas** to design, evaluate, and/or refine a **device** that **minimizes** the **force** on a macroscopic object during a collision.
HS-PS2-3.3	DCI-CCC	Connect **cause** and **effect** relationships to **minimize** the **force** on a macroscopic object during a collision.
HS-PS2-3.4	SEP-CCC	**Apply scientific** and/or **engineering ideas** using **cause** and **effect** relationships to design, evaluate, and/or refine a system.

Details and Clarifications

- **Apply scientific** and/or **engineering ideas** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- Devices that **minimize force** may include, but are NOT limited to:
  - parachute
  - bumper on a moving object
  - cabinet door damper

- **Cause** and **effect** relationships that **minimize force** on a macroscopic object during a collision may include, but are NOT limited to:
  - Force in the direction of a change in momentum is decreased by increasing the time interval of a collision.
  - A change in the total momentum of a system is balanced by changes in the momentum of objects outside the system.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
• Use mathematical representations of phenomena to describe explanations.

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
• Theories and laws provide explanations in science.
• Laws are statements or descriptions of the relationships among observable phenomena.</td><td>PS2.B: Types of Interactions
• Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
• Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 64–67</td><td>pp. 116–118</td><td>pp. 85–87</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 10
Appendix H
p. 5</td><td>Appendix E
p. 7</td><td>Appendix G
pp. 3–5</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment is limited to systems with two objects.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-PS2-4.1	SEP-DCI-CCC	**Use mathematical representations** of Newton's Law of Universal Gravitation and/or Coulomb's Law to describe and/or predict **patterns** in the **gravitational** and/or **electrostatic forces** between objects.
HS-PS2-4.2	SEP-DCI	**Use mathematical representations** of Newton's Law of Universal Gravitation and/or Coulomb's Law to describe **gravitational** and/or **electrostatic forces** between objects.
HS-PS2-4.3	DCI-CCC	Connect **patterns** to **gravitational** and/or **electrostatic forces** between objects.
HS-PS2-4.4	SEP-CCC	**Use mathematical representations** to describe and/or predict patterns.

Details and Clarifications

- **Use mathematical representations** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
  - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems

- Given **mathematical representations** include:
  - Newton's Law of Universal Gravitation: gravitational attraction between two objects is the product of their masses divided by the square of the distance between the objects $\left(F_g = -G\frac{m_1 m_2}{d^2}\right)$
  - Coulomb's Law: electrostatic force between two objects is the product of their individual charges divided by the square of the distance between the objects $\left(F_e = k\frac{q_1 q_2}{d^2}\right)$
- The effects of **gravitational forces** between objects may include, but are NOT limited to:
  - objects with mass are sources of and/or affected by gravitational fields
  - gravitational forces are always attractive

- The effects of **electrostatic forces** between objects may include, but are NOT limited to:
  - objects with electric charges are sources of and/or affected by electric fields
  - electrostatic forces can be attractive or repulsive

- **Patterns** may include, but are NOT limited to:
  - the change in energy of objects interacting through electrical and/or gravitational forces depends on the distance between objects
  - the gravitational force is only attractive because mass is always positive
  - the electrostatic force can be attractive or repulsive because electric charges can be positive or negative

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models. • 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.	**PS2.B: Types of Interactions** • Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. **PS3.A: Definitions of Energy** • "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. *(secondary)*	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 59–61	pp. 116–118 pp. 120–124	pp. 87–89
NGSS Appendices	Appendix F pp. 7–8	Appendix E p. 7	Appendix G pp. 5–6
Clarification Statement	A clarification statement is not provided for this PE.		
Assessment Boundary	Assessment is limited to designing and conducting investigations with provided materials and tools.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS2-5.1	SEP-DCI-CCC	**Plan** and/or **conduct** an **investigation** to provide **evidence** of a **cause and effect** relationship between an **electric current** and a **magnetic field** and/or between a changing **magnetic field** and an **electric current**.
HS-PS2-5.2	SEP-DCI	**Plan** and/or **conduct** an **investigation** to provide **evidence** of an **electric current** and/or a **magnetic field**.
HS-PS2-5.3	DCI-CCC	Use **cause and effect** relationships to connect an **electric current** to a **magnetic field** and/or a changing **magnetic field** to an **electric current**.
HS-PS2-5.4	SEP-CCC	**Plan** and/or **conduct** an **investigation** to produce **evidence** of cause and effect relationships.

Details and Clarifications

- **Plan** and/or **conduct** an **investigation** is expanded to include:
  - planning for and/or producing data to serve as evidence for developing and/or revising models, supporting an explanation, and/or testing a solution
  - planning for and/or evaluating an investigation to identify possible confounding variables and/or to ensure that variables are controlled
  - determining the type, amount, and/or accuracy of data needed to produce reliable measurements and/or considering limitations on the precision of the data (e.g., number of trials, cost, risk, time)
  - selecting appropriate processes, methods, and/or tools to collect, record, analyze, and/or evaluate data
  - predicting what happens to a dependent variable when an independent variable is manipulated
  - identifying failure points and/or describing performance relative to criteria for success

- An **investigation** may include, but is NOT limited to:
  - observing and/or manipulating a source of electrical energy
  - constructing electric circuits with flowing electric current
  - using a tool to detect and/or measure an electric current
  - using a tool to detect and/or measure changes in a magnetic field

- Examples of **evidence** of a **cause and effect** relationship between an **electric current** and a **magnetic field** may include, but are NOT limited to:
  - an electromagnet producing an electric current and attracting metal objects
  - the needle of a magnetic compass moving when the compass is placed near wire carrying an electric current

- Examples of **evidence** of a **cause and effect** relationship between a changing **magnetic field** and an **electric current** may include, but are NOT limited to:
  - magnets rotating around a wire inducing an electric current in the wire

Performance Expectation	**HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate scientific and technical information (e.g., about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	**PS2.B: Types of Interactions** • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 74–77	pp. 116–118	pp. 96–98
NGSS Appendices	Appendix F p. 15	Appendix E p. 7	Appendix G pp. 9–10
Clarification Statement	Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.		
Assessment Boundary	Assessment is limited to provided molecular structures of specific designed materials.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS2-6.1	SEP-DCI-CCC	**Communicate information** about the role of **attraction** and/or **repulsion** of electric charges at the atomic scale in determining the **structure**, properties, and/or transformations of matter and/or the resulting **function** of designed materials.
HS-PS2-6.2	SEP-DCI	**Communicate information** about atomic-level **attraction** and/or **repulsion**, properties, and/or transformations of matter in designed materials.
HS-PS2-6.3	DCI-CCC	Use the **attraction** and/or **repulsion** of electric charges at the atomic scale to determine the **structure**, properties, and/or transformations of matter and/or the resulting **function** of designed materials.
HS-PS2-6.4	SEP-CCC	**Communicate information** about the structure and/or function of a system.

Details and Clarifications

- **Communicate information** is expanded to include:
  - identifying scientific and/or technical evidence, concepts, processes, and/or information
  - evaluating the validity and/or reliability of claims from different sources
  - integrating multiple sources of information to construct and/or support an explanation
  - summarizing complex information

- **Information** formats may include, but are NOT limited to:
  - text
  - diagrams
  - graphs
  - tables
  - models
  - animations
  - equations

- Examples of **attraction** and/or **repulsion** may include, but are NOT limited to:
  - attractive and/or repulsive electrical forces between molecules (e.g., intermolecular forces)
  - attraction and/or repulsion among electric charges among atoms within a molecule (e.g., chemical bonds)

- Examples of **structure** and **function** relationships may include, but are NOT limited to:
  - how the structure and/or properties of matter and/or the types of interactions of matter at the atomic scale determine macroscopic properties of a designed material
  - how a designed material's properties make it suitable for use in its designed function

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Create a computational model or simulation of a phenomenon, designed device, process, or system.	**PS3.A: Definitions of Energy** • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. **PS3.B: Conservation of Energy and Energy Transfer** • Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. • The availability of energy limits what can occur in any system.	**Systems and System Models** • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. **Connections to Nature of Science** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes the universe is a vast single system in which basic laws are consistent.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 64–67	pp. 120–124 pp. 124–126	pp. 91–94
NGSS Appendices	Appendix F p. 10	Appendix E p. 7	Appendix G pp. 7–8 Appendix H p. 6
Clarification Statement	Emphasis is on explaining the meaning of mathematical expressions used in the model.		
Assessment Boundary	Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS3-1.1	SEP-DCI-CCC	**Create** a **computational model** to **calculate** the **change** in **energy** of **one component** in a **system** when the **change** in **energy** of the **other component**(s) and/or **energy flows in** and/or **out** of the **system** are known.
HS-PS3-1.2	SEP-DCI	**Create** a **computational model** to calculate **changes** in **energy.**
HS-PS3-1.3	DCI-CCC	Connect the **change** in **energy** of **one component** in a **system** to the **change** in **energy** of the **other component**(s) and/or to the **energy flows in** and/or **out** of the **system**.
HS-PS3-1.4	SEP-CCC	**Create** a **computational model** to describe the behavior of a system.

Details and Clarifications

- **Create** a **computational model** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
  - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems

- Components of a **computational model** that **calculates the energy** of **one component** in a system when the **change** in **energy** of the **other component(s)** and/or **energy flows in** and/or **out** of the system are known may include, but are NOT limited to:
  - boundaries of a system
  - initial and/or final temperatures of components
  - masses of components
  - algebraic constants (e.g., specific heat)
  - initial and/or final energies of components (e.g., energy in fields, thermal energy, kinetic energy)
  - the energy flows into, out of, and/or within a system
  - equations used to calculate energy changes (e.g., $Q = m \cdot C \cdot \Delta T$)
  - the energy change of a system equaling the energy transferred into and/or out of the system
  - energy being conserved during transfers and/or conversions

- Examples of **energy flows in** and/or **out** of a **system** may include, but are NOT limited to:
  - thermal energy transferring from a system to another system
  - kinetic energy converting to sound and/or thermal energy during a collision between objects and/or systems

<table>
<tr><td>Performance Expectation</td><td colspan="3">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 positions of particles (objects).</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>PS3.A: Definitions of Energy
• Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
• These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.</td><td>Energy and Matter
• Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 56–59</td><td>pp. 120–124</td><td>pp. 94–96</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 6</td><td>Appendix E
p. 7</td><td>Appendix G
pp. 8–9</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-PS3-2.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** to illustrate that **energy** at the **macroscopic scale** can be accounted for as a combination of **energy** associated with the **motions** and **relative positions** of particles (objects) within a system.
HS-PS3-2.2	SEP-DCI	**Develop** and/or **use** a **model** to illustrate the **motions** and **relative positions** of particles (objects) within a system.
HS-PS3-2.3	DCI-CCC	Connect **energy** at the **macroscopic scale** to a combination of **energy** associated with the **motions** and **relative positions** of particles (objects) within a system.
HS-PS3-2.4	SEP-CCC	**Develop** and/or **use** a **model** to illustrate transfers of energy within and/or between systems.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- **Models** may include, but are NOT limited to:
  - components of the system and/or the surroundings
  - energy flows between a system and the surroundings
  - macroscopic and/or molecular/atomic representations within the system
  - energy on a macroscopic scale (e.g., motion, sound, light, thermal energy, potential energy, energy in fields)
  - energy on a molecular/atomic scale (e.g., kinetic energy of particles, potential energy)

- Examples of **energy** at the **macroscopic scale** as a combination of **energy** of the **motions** and **relative positions** of particles may include, but are NOT limited to:
  - charged and/or magnetic objects moving away from each other causing a change in field energy
  - thermal energy including the vibrations and/or movements of particles in matter
  - energy increases being balanced by energy decreases as energy is transferred among objects and/or energy fields

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
• 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.</td><td>PS3.A: Definitions of Energy
• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

PS3.D: Energy in Chemical Processes
• Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

ETS1.A: Defining and Delimiting an Engineering Problem
• Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary)</td><td>Energy and Matter
• Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering and Technology on Society and the Natural World
• Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 67–71</td><td>pp. 120–124
pp. 128–130
pp. 204–206</td><td>pp. 94–96
pp. 212–214</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 11–12</td><td>Appendix E
p. 7
Appendix E
p. 8
Appendix I
pp. 1–7</td><td>Appendix G
pp. 8–9
Appendix J
pp. 3–4</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-PS3-3.1	SEP-DCI-CCC	**Design**, **evaluate**, and/or **refine** a **device** that **converts energy** from one form into another form in a **system** while meeting given **criteria** and/or **constraints**.
HS-PS3-3.2	SEP-DCI	**Design**, **evaluate**, and/or **refine** a **device** that meets given **criteria** and/or **constraints**.
HS-PS3-3.3	DCI-CCC	Analyze a system to track the **conversion** of **energy** from one form into another form.
HS-PS3-3.4	SEP-CCC	Due to a strong overlap between the DCI and CCC, items are not coded HS-PS3-3.4.

Details and Clarifications

- **Design**, **evaluate**, and/or **refine** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- **Devices** that **convert energy** may include, but are NOT limited to:
  - a battery that converts chemical energy into electricity
  - a heater that converts electrical energy into thermal energy
  - a bulb that converts electrical energy into light and/or thermal energy

- **Evaluate** a **system** may include, but is NOT limited to:
  - describing energy inputs to, outputs of, and/or flows within a defined system

- **Criteria** for determining the success of the device may include, but are NOT limited to:
  - minimizes transfer of energy out of a given system
  - uses materials with desired and/or required properties
  - provides a specific benefit to civilization
  - low impact on the environment
  - low risk of injury
  - effective in solving specific aspects of the given problem

- **Constraints** that can limit the success of the device may include, but are NOT limited to:
  - high cost
  - low availability of materials and/or resources
  - low efficiency of energy conversion
  - physical, social, ethical, aesthetic, and/or time issues

Performance Expectation	**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).		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • 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.	**PS3.B: Conservation of Energy and Energy Transfer** • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **PS3.D: Energy in Chemical Processes** • Although energy cannot be destroyed, it can be converted to less useful forms — for example, to thermal energy in the surrounding environment.	**Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 59–61	pp. 125–126 pp. 128–130	pp. 91–94
NGSS Appendices	Appendix F pp. 7–8	Appendix E pp. 7–8	Appendix G pp. 7–8
Clarification Statement	Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.		
Assessment Boundary	Assessment is limited to investigations based on materials and tools provided to students.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS3-4.1	SEP-DCI-CCC	**Plan** and/or **conduct** an **investigation** to provide **evidence** that the **transfer** of **thermal energy** between components within a **closed system** results in a more **uniform energy distribution**.
HS-PS3-4.2	SEP-DCI	**Plan** and/or **conduct** an **investigation** to provide **evidence** that the **transfer** of **thermal energy** between objects results in a more **uniform energy distribution**.
HS-PS3-4.3	DCI-CCC	Connect the inputs, outputs, and/or boundaries of **a closed system** to the **transfer** of **thermal energy** between components of the system that results in a more **uniform energy distribution**.
HS-PS3-4.4	SEP-CCC	**Plan** and/or **conduct** an **investigation** to provide **evidence** supporting the inputs, outputs, and/or boundaries of a closed system.

Details and Clarifications

- **Plan** and/or **conduct** an **investigation** is expanded to include:
  - planning for and/or producing data to serve as evidence for developing and/or revising models, supporting an explanation, and/or testing a solution
  - planning for and/or evaluating an investigation to identify possible confounding variables and/or to ensure that variables are controlled
  - determining the type, amount, and/or accuracy of data needed to produce reliable measurements and/or considering limitations on the precision of the data (e.g., number of trials, cost, risk, time)
  - selecting appropriate processes, methods, and/or tools to collect, record, analyze, and/or evaluate data
  - predicting what happens to a dependent variable when an independent variable is manipulated
  - identifying failure points and/or describing performance relative to criteria for success

- **Evidence** that the **transfer** of **thermal energy** results in a more **uniform energy distribution** may include, but is NOT limited to:
  - a decrease in temperature of a warmer object corresponding to an increase in temperature of a cooler object in a closed system
  - the thermal energy lost by a warmer object equaling the thermal energy gained by a cooler object in a closed system
  - temperatures of a warmer object and a cooler object in a closed system continuing to change until the temperatures of both objects are equal
  - some of the thermal energy of a system transferring to the surroundings

- Parts of a **closed system** may include, but are NOT limited to:
  - boundaries (e.g., an insulated container)
  - initial and final conditions (e.g., temperatures and/or masses of components)

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**PS3.C: Relationship Between Energy and Forces** • When two objects interacting through a field change relative position, the energy stored in the field is changed.	**Cause and Effect** • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 56–59	pp. 126–127	pp. 87–89
NGSS Appendices	Appendix F p. 6	Appendix E p. 8	Appendix G pp. 5–6
Clarification Statement	Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.		
Assessment Boundary	Assessment is limited to systems containing two objects.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS3-5.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** to illustrate the **cause and effect** relationships between **force**, changes in **position**, and/or changes in **energy** for two **objects interacting** in a magnetic or electric field.
HS-PS3-5.2	SEP-DCI	**Develop** and/or **use** a **model** to illustrate the **forces**, changes in **position**, and/or changes in **energy** for two **objects** in a magnetic or electric field.
HS-PS3-5.3	DCI-CCC	Use **cause and effect** relationships to connect **force** to changes in **position** and/or changes in **energy** for two **objects interacting** in a magnetic or electric field.
HS-PS3-5.4	SEP-CCC	**Develop** and/or **use** a **model** based on evidence to illustrate cause and effect relationships for a system.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or to describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- **Models** of two **objects interacting** may include, but are NOT limited to diagrams, texts, and/or tables describing:
  - initial positions and/or velocities
  - relative magnitude and/or direction of net forces
  - the nature of interaction (e.g., electric, magnetic)
  - the force and/or energy of a field (e.g., magnetic, electric)

- **Cause and effect** relationships between **force** and changes in **position** and/or changes in **energy** may include, but are NOT limited to:
  - When two objects interact in a field, energy is transferred from one object to the second object.
  - When two objects change their relative positions, the energy stored in a field changes.
  - When forces exerted on objects change, energy changes.

Performance Expectation	**HS-PS4-1** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.	**PS4.A: Wave Properties** • The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 64–67	pp. 131–133	pp. 87–89
NGSS Appendices	Appendix F p. 10	Appendix E p. 8	Appendix G pp. 5–6
Clarification Statement	Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.		
Assessment Boundary	Assessment is limited to algebraic relationships and describing those relationships qualitatively.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS4-1.1	SEP-DCI-CCC	**Use mathematical representations** to support a claim about **cause and effect** relationships between **wave speed, frequency**, and/or **wavelength** as a wave travels through various **media**.
HS-PS4-1.2	SEP-DCI	**Use mathematical representations** to support a claim about **wave speed, frequency**, and/or **wavelength** as a wave travels through various **media**.
HS-PS4-1.3	DCI-CCC	Apply **cause and effect** relationships to changes in **wave speed, frequency**, and/or **wavelength** as a wave travels through different **media**.
HS-PS4-1.4	SEP-CCC	**Use mathematical representations** to make or support a claim about cause and effect relationships.

Details and Clarifications

- **Use mathematical representations** is expanded to include:
    - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
    - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
    - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems

- **Mathematical representations** may include, but are NOT limited to:
    - mathematical relationships between speed, frequency, and/or wavelength for waves traveling in a specific medium, based on the given formula: $v = \lambda f$
    - mathematical comparison of speed, frequency, and/or wavelength for different waves traveling through different media
    - data showing changes in wave speed as a result of changes in medium
    - a simulation showing relationships between speed, frequency, and/or wavelength for wave traveling through various media

- **Relationships** between the **wavelength** and **frequency** of a **wave** and the **speed** and **medium** may include, but are NOT limited to:
    - wavelength is proportional to wave speed
    - frequency and wavelength are inversely proportional
    - wave speed depends on the properties of the medium (e.g., air, glass, water)

- **Cause and effect** relationships may include, but are NOT limited to:
    - when a wave meets the surface between two different materials or conditions (e.g., air and water), the wave speed can change
    - change of speed of the wave when passing from one medium to another can cause the wavelength to change

Performance Expectation	**HS-PS4-2** Evaluate questions about the advantages of using a digital transmission and storage of information.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Asking Questions and Defining Problems Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set or the suitability of a design.	**PS4.A: Wave Properties** • Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.	**Stability and Change** • Systems can be designed for greater or lesser stability. **Connections to Engineering, Technology, and Applications of Science** **Influence of Engineering, Technology, and Science on Society and the Natural World** • Modern civilization depends on major technological systems. • Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 54–56	pp. 131–133	pp. 98–101 pp. 210–214
NGSS Appendices	Appendix F pp. 4–5	Appendix E p. 5	Appendix G pp. 10–11 Appendix J pp. 3–4
Clarification Statement	Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.		
Assessment Boundary	An assessment boundary is not provided for this PE.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS4-2.1	SEP-DCI-CCC	**Ask** and/or **evaluate questions** about the **advantages** and/or **disadvantages** of using **digital transmission** and/or **digital storage** of information.
HS-PS4-2.2	SEP-DCI	**Ask** and/or **evaluate questions** about using **digital transmission** and/or **digital storage** of information.
HS-PS4-2.3	DCI-CCC	Connect **advantages** and/or **disadvantages** to using **digital transmission** and/or **digital storage** of information.
HS-PS4-2.4	SEP-CCC	**Ask** and/or **evaluate questions** about the stability of a system.

Details and Clarifications

- **Ask** and/or **evaluate questions** is expanded to include:
  - asking and/or identifying questions that arise from observation and/or investigation to seek additional information
  - asking questions to determine quantitative and/or qualitative relationships, between independent and dependent variables
  - asking questions to refine a model, an explanation, and/or an engineering problem
  - asking questions to determine if a question is testable and/or relevant
  - asking questions that frame a hypothesis based on observations and/or scientific principles
  - defining a design problem that involves the development of a process and/or system with interacting components
  - describing social, technical, and/or environmental criteria for a successful solution
  - describing social, technical, and/or environmental constraints that could limit the success of a solution

- **Digital transmission** may include, but is NOT limited to:
  - a digital signal from a computer transmitted through a router to the internet
  - sharing a computer file between computers, using a thumb drive

- **Digital storage** may include, but is NOT limited to:
  - a picture stored as the values of an array of pixels
  - a file on a computer (e.g., spreadsheet, document, music)
  - a post to a website

- **Advantages** of using a **digital transmission** and/or **digital storage** of information may include, but are NOT limited to:
  - relatively less degradation over time
  - relatively fast transfer of information
  - relatively rapid copying and sharing
  - relatively broad access
  - relatively large data storage
  - relatively less susceptibility to interference

- **Disadvantages** of using a **digital transmission** and/or **digital storage** of information may include, but are NOT limited to:
  - increased chance of accidental deletion
  - increased chance of theft through copying

Performance Expectation	**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.		
	Science & Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Dimensions	**Engaging in Argument from Evidence** Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment. The science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.	**PS4.A: Wave Properties** • [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) **PS4.B: Electromagnetic Radiation** • Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.	**Systems and System Models** • Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions — including energy, matter and information flows — within and between systems at different scales.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 71–74	pp. 131–133 pp. 133–136	pp. 91–94
NGSS Appendices	Appendix F pp. 13–14 Appendix H p. 5	Appendix E p. 8	Appendix G pp. 7–8
Clarification Statement	Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.		
Assessment Boundary	Assessment does not include using quantum theory.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS4-3.1	SEP-DCI-CCC	**Evaluate** the **claims**, **evidence**, and/or **reasoning** behind the idea that electromagnetic radiation can be described by either a **wave model** or a **particle model**, and/or that for some phenomena one model is more useful than the other.
HS-PS4-3.2	SEP-DCI	**Evaluate** the **claims**, **evidence**, and/or **reasoning** behind the idea that electromagnetic radiation has **wave** properties and/or **particle** properties**.**
HS-PS4-3.3	DCI-CCC	**Use** a **wave model** or a **particle model** to describe **electromagnetic radiation** and/or describe that for some phenomena one model is more useful than the other.
HS-PS4-3.4	SEP-CCC	**Evaluate** the **claims, evidence,** and/or **reasoning** behind the explanation of the interactions within and/or among systems**.**

Details and Clarifications

- **Evaluate** the **claims, evidence,** and/or **reasoning** is expanded to include:
  - describing criteria used to critique claims
  - using evidence to compare and/or evaluate competing arguments and/or solutions
  - using evidence to determine the merit of an argument and/or an explanation
  - using evidence to construct and/or support an argument and/or a claim
  - evaluating competing design solutions to real-world problems using scientific ideas and/or evidence and/or relevant economic, societal, and/or environmental considerations

- Examples of situations that a **wave model** is used to describe may include, but are NOT limited to:
  - resonance
  - interference
  - diffraction
  - changing electric and/or magnetic fields

- Examples of situations that a **particle model** is used to describe may include, but are NOT limited to:
  - photoelectric effect

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible.	**PS4.B: Electromagnetic Radiation** • When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.	**Cause and Effect** • Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 74–77	pp. 133–136	pp. 87–89
NGSS Appendices	Appendix F p. 15	Appendix E p. 8	Appendix G pp. 5–6
Clarification Statement	Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.		
Assessment Boundary	Assessment is limited to qualitative descriptions.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS4-4.1	SEP-DCI-CCC	**Evaluate** the validity and/or reliability of **claims** in published materials about **cause and effect** relationships between different **frequencies** and/or **wavelengths** of electromagnetic radiation and their absorption by **matter**.
HS-PS4-4.2	SEP-DCI	**Evaluate** the validity and/or reliability of **claims** in published materials about different **frequencies** and/or **wavelengths** of electromagnetic radiation.
HS-PS4-4.3	DCI-CCC	Use **cause and effect** relationships to connect different **frequencies** and/or **wavelengths** of electromagnetic radiation and their absorption by **matter**.
HS-PS4-4.4	SEP-CCC	**Evaluate** the validity and/or reliability of **claims** in scientific texts about cause and effect relationships in a system.

Details and Clarifications

- **Evaluate** the validity and reliability of **claims** is expanded to include:
  - identifying scientific and/or technical evidence, concepts, processes, and/or information
  - evaluating the validity and/or reliability of claims from different sources
  - integrating multiple sources of information to construct and/or support an explanation
  - summarizing complex information

- Information formats may include, but are NOT limited to:
  - text
  - diagrams
  - graphs
  - tables
  - models
  - animations
  - equations

- **Claims** may include, but are NOT limited to:
  - comparing the effect of different wavelengths and/or frequencies of radiation on a molecule, cell, or organism
  - describing the effect of a single wavelength of radiation on a molecule, cell, or organism
  - comparing the effect of different wavelengths and/or frequencies of radiation on the temperature of an object

- **Cause and effect** relationships between different **frequencies** and/or **wavelengths** of electromagnetic radiation and their absorption by **matter** may include, but are NOT limited to:
  - waves with wavelengths and/or frequencies that transfer less energy (e.g., visible light) increasing the temperature of matter
  - waves with wavelengths and/or frequencies that transfer more energy (e.g., ultraviolet, X-ray, gamma ray) ionizing atoms and/or damaging living cells

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate 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 (including orally, graphically, textually, and mathematically).	**PS3.D: Energy in Chemical Processes** • Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. *(secondary)* **PS4.A: Wave Properties** • Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. **PS4.B: Electromagnetic Radiation** • Photoelectric materials emit electrons when they absorb light of a high-enough frequency. **PS4.C: Information Technologies and Instrumentation** • Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.	**Cause and Effect** • Systems can be designed to cause a desired effect. **Connections to Engineering, Technology, and Applications of Science** **Interdependence of Science, Engineering, and Technology** • Science and engineering complement each other in the cycle known as research and development (R&D). **Influence of Engineering, Technology, and Science on Society and the Natural World** • Modern civilization depends on major technological systems.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 74–77	pp. 128–130 pp. 131–133 pp. 133–136 pp. 136–137	pp. 87–89 pp. 210–214
NGSS Appendices	Appendix F p. 15	Appendix E p. 8	Appendix G pp. 5–6 Appendix J pp. 3–4
Clarification Statement	Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.		
Assessment Boundary	Assessments are limited to qualitative information. Assessments do not include band theory.		

Items may ask students to:

Code	Alignment	Item Specification
HS-PS4-5.1	SEP-DCI-CCC	**Communicate** technical **information** about **cause and effect** relationships in **technological devices** designed to use principles of **wave behavior** and/or **wave interactions** with **matter** to **transmit** and/or **capture information** and/or **energy**.
HS-PS4-5.2	SEP-DCI	**Communicate** technical **information** about **technological devices** that use **waves** and/or **matter** to **transmit** and/or **capture information** and/or **energy**.
HS-PS4-5.3	DCI-CCC	Use **cause and effect** relationships in **technological devices** to connect **wave behavior** and/or **wave interactions** with **matter** to the **transmission** and/or **capture** of **information** and/or **energy**.
HS-PS4-5.4	SEP-CCC	**Communicate** technical **information** about systems that are designed to cause a desired effect.

Details and Clarifications

- **Communicate** technical **information** is expanded to include:
  - identifying scientific and/or technical evidence, concepts, processes, and/or information
  - evaluating the validity and/or reliability of claims from different sources
  - integrating multiple sources of information to construct and/or support an explanation
  - summarizing complex information

- **Information** formats may include, but are NOT limited to:
  - text
  - diagrams
  - graphs
  - tables
  - models
  - animations
  - equations

- **Wave behavior** and/or **wave interactions** with **matter** may include, but are NOT limited to:
  - waves combining with other waves to produce complex information
  - waves being refracted, reflected, or transmitted at a boundary
  - light waves shining on a metal, causing electrons to be ejected from the surface of the metal
  - radiant energy being converted to thermal energy when absorbed by a material

- **Cause and effect** relationships in **technological devices** designed to **transmit** and/or **capture information** and/or **energy** may include, but are NOT limited to:
  - solar cells capturing solar energy and converting it to electricity
  - computers transmitting information as a series of wave pulses
  - medical imaging devices capturing and interpreting signals from waves that are traveling through the body

Life Sciences

Disciplinary Core Ideas:

- 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

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
• Construct 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.</td><td>LS1.A: Structure and Function
• Systems of specialized cells within organisms help them perform the essential functions of life.
• All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (Note: This Disciplinary Core Idea is also addressed by HS-LS3-1.)</td><td>Structure and Function
• Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 67–71</td><td>pp. 143–145</td><td>pp. 96–98</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 11–12</td><td>Appendix E
p. 4</td><td>Appendix G
pp. 9–10</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">A clarification statement is not provided for this PE.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-LS1-1.1	SEP-DCI-CCC	**Construct** an **explanation** based on **evidence** for how the **structure** of **DNA** determines the **structure** of **proteins** and/or how **systems** of **specialized cells** use proteins to carry out essential life **functions**.
HS-LS1-1.2	SEP-DCI	**Construct** an **explanation** based on **evidence** for how **DNA** determines the **proteins** produced in a cell and/or how **specialized cells** use proteins.
HS-LS1-1.3	DCI-CCC	Connect the **structure** of **DNA** and/or **structure** of **proteins** and/or the essential life **functions** of **systems** of **specialized cells**.
HS-LS1-1.4	SEP-CCC	**Construct** an **explanation** based on evidence for how the structure of an object relates to its function.

Details and Clarifications

- **Construct an explanation** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- Examples of **evidence** may include, but are NOT limited to:
  - All cells contain DNA.
  - DNA is made of genes.
  - The DNA sequence in a gene codes for a specific protein.
  - Proteins are composed of amino acids.

- Examples of how the **structure** of **DNA** determines the **structure** of **proteins** may include, but are NOT limited to:
  - The sequence of nucleotides in a gene determines the sequence of amino acids in proteins.
  - A mutation in a gene may alter the sequence of amino acids in and/or the shape of a protein.

- Examples of how **systems** of **specialized cells** use proteins to carry essential life **functions** may include, but are NOT limited to:
  - enzymes combining with other molecules inside or outside a cell to catalyze reactions
  - protein hormones regulating the function of a tissue and/or a cell
  - cells producing the structural proteins that are components of cells and/or tissues
  - different proteins being produced in different specialized cells

Performance Expectation	**HS-LS1-2** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.A: Structure and Function** • Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 56–59	pp. 143–145	pp. 91–94
NGSS Appendices	Appendix F p. 6	Appendix E p. 4	Appendix G pp. 7–8
Clarification Statement	Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.		
Assessment Boundary	Assessment does not include interactions and functions at the molecular or chemical reaction level.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS1-2.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** to illustrate **hierarchical organization** of **interacting systems** within multicellular organisms.
HS-LS1-2.2	SEP-DCI	**Develop** and/or **use** a **model** to illustrate **hierarchical organization** within multicellular organisms.
HS-LS1-2.3	DCI-CCC	Connect **hierarchical organization** to **interacting systems** in multicellular organisms.
HS-LS1-2.4	SEP-CCC	**Develop** and/or **use** a **model** to illustrate relationships in interacting systems.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
    - developing, revising, and/or using a model to generate data
    - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
    - using a given complete or partial model to make predictions and/or describe phenomena
    - revising a given complete or partial model
    - describing the limitations of a complete or partial model
    - comparing models of a given system

- **Models** may include, but are NOT limited to, a diagram, simulation, or written description of:
    - the functions (e.g., nutrient uptake, motion) and/or parts (e.g., organs, tissues, cells) of major body systems (e.g., circulatory, digestive, muscular, nervous, skeletal, endocrine, excretory, respiratory) in relation to the overall function of an organism
    - interactions between two or more body systems and/or subsystems within a body system
    - interactions between body systems and/or system components at different scales (e.g., cells, organs)

- **Hierarchical organization** of multicellular organisms may include, but is NOT limited to:
    - cells with interacting organelles
    - tissues composed of interacting cells
    - organs composed of interacting tissues
    - organ systems composed of interacting organs
    - organisms composed of interacting organ systems

- **Interacting systems** may include, but are NOT limited to:
    - the circulatory system delivers oxygen to/removes waste from systems in an organism
    - cardiac muscle requires nerve cell stimulus for heartbeats

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Planning and Carrying Out Investigations
Planning and carrying out investigations in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.
• 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.

Connections to Nature of Science

Scientific Investigations Use a Variety of Methods
• Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings.</td><td>LS1.A: Structure and Function
• Feedback mechanisms maintain a living system’s internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.</td><td>Stability and Change
• Feedback (negative or positive) can stabilize or destabilize a system.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 59–61</td><td>pp. 143–145</td><td>pp. 98–101</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 7–8
Appendix H
p. 5</td><td>Appendix E
p. 4</td><td>Appendix G
pp. 10–11</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment does not include the cellular processes involved in the feedback mechanism.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-LS1-3.1	SEP-DCI-CCC	**Plan** and/or **conduct** an **investigation** to provide **evidence** that **feedback mechanisms** maintain **homeostasis.**
HS-LS1-3.2	SEP-DCI	**Plan** and/or **conduct** an **investigation** to provide **evidence** that organisms maintain **homeostasis.**
HS-LS1-3.3	DCI-CCC	Connect **feedback mechanisms** to the maintenance of **homeostasis.**
HS-LS1-3.4	SEP-CCC	**Plan** and/or **conduct** an **investigation** to provide **evidence** for stability and/or change in a system.

Details and Clarifications

- **Plan** and/or **conduct** an **investigation** is expanded to include:
  - planning for and/or producing data to serve as evidence for developing and/or revising models, supporting an explanation, and/or testing a solution
  - planning for and/or evaluating an investigation to identify possible confounding variables and/or to ensure that variables are controlled
  - determining the type, amount, and/or accuracy of data needed to produce reliable measurements and/or considering limitations on the precision of the data (e.g., number of trials, cost, risk, time)
  - selecting appropriate processes, methods, and/or tools to collect, record, analyze, and/or evaluate data
  - predicting what happens to a dependent variable when an independent variable is manipulated
  - identifying failure points and/or describing performance relative to criteria for success

- Types of **evidence** may include, but are NOT limited to:
  - measurements of changes (e.g., temperature, humidity) in an external environment
  - measurements of changes in an organism (e.g., blood pressure, rate of photosynthesis)

- Examples of **feedback mechanisms** that maintain **homeostasis** may include, but are NOT limited to:
  - changes in blood vessel diameter, shivering, and/or sweat production to stabilize internal body temperature
  - changes in stomata to stabilize internal moisture, temperature, and/or gas levels (e.g., O_2, CO_2)

Performance Expectation	**HS-LS1-4** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.B: Growth and Development of Organisms** • In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 56–59	pp. 145–147	pp. 91–94
NGSS Appendices	Appendix F p. 6	Appendix E p. 4	Appendix G pp. 7–8
Clarification Statement	A clarification statement is not provided for this PE.		
Assessment Boundary	Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS1-4.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** to illustrate the role of **mitosis** and/or **differentiation** in **producing** and/or **maintaining complex organisms**.
HS-LS1-4.2	SEP-DCI	**Develop** and/or **use** a **model** to describe **mitosis** and/or **differentiation**.
HS-LS1-4.3	DCI-CCC	Connect the processes of **mitosis** and/or **differentiation** to **producing** and/or **maintaining complex organisms**.
HS-LS1-4.4	SEP-CCC	**Develop** and/or **use** a **model** to illustrate interactions within or among systems.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or to describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- Components of a model that illustrates **mitosis** and/or **differentiation** may include, but are NOT limited to:
  - genetic material from two parents
  - parent and/or daughter cells
  - daughter cells receiving identical genetic information from parent cell or fertilized egg
  - differentiated cells within a complex organism

- Examples of the role of **mitosis** in **producing** and/or **maintaining complex organisms** may include, but are NOT limited to:
  - daughter cells receiving identical genetic information from a parent cell and/or fertilized egg
  - differentiated cells, tissues, and/or organs interacting with one another to keep a multicellular organism alive (e.g., damaged tissues being healed)
  - genes being expressed in one type of cell and not being expressed in another type of cell, leading to the development of tissues and/or organs

Performance Expectation	**HS-LS1-5** Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.	**Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 56–59	pp. 147–148	pp. 94–96
NGSS Appendices	Appendix F p. 6	Appendix E p. 4	Appendix G pp. 8–9
Clarification Statement	Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.		
Assessment Boundary	Assessment does not include specific biochemical steps.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS1-5.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** to illustrate that **photosynthesis** transforms **light energy** into **stored chemical energy**.
HS-LS1-5.2	SEP-DCI	**Develop** and/or **use** a **model** to illustrate the inputs and outputs of **photosynthesis**.
HS-LS1-5.3	DCI-CCC	Describe the process of **photosynthesis** and/or that photosynthesis transforms **light energy** into **stored chemical energy**.
HS-LS1-5.4	SEP-CCC	**Develop** and/or **use** a **model** to illustrate that energy and/or matter is transferred within a system and/or between systems.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- Types of **models** may include, but are NOT limited to:
  - diagrams
  - chemical equations
  - conceptual models

- Components of a **model** of **photosynthesis** may include, but are NOT limited to:
  - reactant molecules (i.e., carbon dioxide, water)
  - product molecules (i.e., glucose, oxygen)
  - breaking and/or forming of chemical bonds
  - rearranging of matter when existing chemical bonds are broken and new chemical bonds are formed
  - light energy as an input

- Examples of **light energy** transforming into **stored chemical energy** during photosynthesis may include, but are NOT limited to:
  - light energy being absorbed to break chemical bonds in carbon dioxide and water
  - energy being released during bond formation in glucose and oxygen
  - the amount of chemical energy stored during photosynthesis being the difference between the energies of the chemical bonds of the reactants and the chemical bonds of the products

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • 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.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. • As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.	**Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 67–71	pp. 147–148	pp. 94–96
NGSS Appendices	Appendix F pp. 11–12	Appendix E p. 4	Appendix G pp. 8–9
Clarification Statement	Emphasis is on using evidence from models and simulations to support explanations.		
Assessment Boundary	Assessment does not include the details of the specific chemical reactions or identification of macromolecules.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS1-6.1	SEP-DCI-CCC	**Construct** and/or **revise** an **explanation** based on **evidence** that as **matter cycles** and/or **energy flows** through living systems, the chemical elements in **sugar molecules** may combine with **other elements** to form **large carbon-based molecules**.
HS-LS1-6.2	SEP-DCI	**Construct** and/or **revise** an **explanation** based on **evidence** that the chemical elements in **sugar molecules** may combine with **other elements** to form **large carbon-based molecules**.
HS-LS1-6.3	DCI-CCC	Connect the **cycling** of **matter** and/or **flow** of **energy** in living systems to the combination of chemical elements in **sugar molecules** with other elements to form **large carbon-based molecules.**
HS-LS1-6.4	SEP-CCC	**Construct** and/or **revise** an **explanation** based on evidence about the cycling of matter and/or flow of energy into, out of, and/or within a system.

Details and Clarifications

- **Construct** and/or **revise** an **explanation** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- **Large carbon-based molecules** may include, but are NOT limited to:
  - amino acids
  - DNA
  - proteins
  - fats
  - sugars other than glucose

- Examples of **evidence** of **matter cycling** when **sugar molecules** combine to form other **large carbon-based molecules** may include, but is NOT limited to:
  - Carbon, hydrogen, and oxygen are the main components of sugar molecules, amino acids, and other large carbon-based molecules.
  - Atoms from food molecules are rearranged during chemical reactions in living systems (e.g., cellular respiration).

- Examples of **evidence** of **energy flowing** when **sugar molecules** combine to form other **large carbon-based molecules** may include, but is NOT limited to:
  - Energy is released during some chemical reactions (e.g., cellular respiration).
  - Energy drives reactions that form amino acids and/or other large carbon-based molecules.

Performance Expectation	**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.		
	Science & Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Dimensions	**Developing and Using Models** Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. • As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.	**Energy and Matter** • Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 56–59	pp. 147–148	pp. 94–96
NGSS Appendices	Appendix F p. 6	Appendix E p. 4	Appendix G pp. 8–9
Clarification Statement	Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.		
Assessment Boundary	Assessment should not include identification of the steps or specific processes involved in cellular respiration.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS1-7.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** to illustrate that **cellular respiration** is a chemical process that results in a **net transfer** of **energy**.
HS-LS1-7.2	SEP-DCI	**Develop** and/or **use** a **model** to illustrate that **cellular respiration** is a chemical process.
HS-LS1-7.3	DCI-CCC	Connect a **net transfer** of **energy** to the **cellular respiration** process.
HS-LS1-7.4	SEP-CCC	**Develop** and/or **use** a **model** to illustrate that energy and/or matter is transferred within a system and/or between systems.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or to describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- Types of **models** may include, but are NOT limited to:
  - chemical equations
  - conceptual models

- Components of a **model** of **cellular respiration** may include, but are NOT limited to:
  - reactant molecules (i.e., glucose, oxygen)
  - product molecules (i.e., water, carbon dioxide)
  - breaking and/or forming of chemical bonds
  - rearranging of matter when existing chemical bonds are broken and new chemical bonds are formed
  - transfer of energy

- Examples of a **net transfer** of **energy** may include, but are NOT limited to:
  - energy being required to break the bonds of sugar and oxygen
  - energy released during bond formation in carbon dioxide and water exceeding the energy input to break bonds in glucose and oxygen
  - plant and/or animal cells using released energy to sustain life processes (e.g., movement, growth, reproduction)

Performance Expectation	**HS-LS2-1** Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Using Mathematics and Computational Thinking Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical and/or computational representations of phenomena or design solutions to support explanations.	**LS2.A: Interdependent Relationships in Ecosystems** • Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.	**Scale, Proportion, and Quantity** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 64–67	pp. 150–152	pp. 89–91
NGSS Appendices	Appendix F p. 10	Appendix E p. 5	Appendix G pp. 6–7
Clarification Statement	Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.		
Assessment Boundary	Assessment does not include deriving mathematical equations to make comparisons.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS2-1.1	SEP-DCI-CCC	**Use mathematical** and/or **computational representations** to support explanations of **factors** that affect **carrying capacity** of **ecosystems** at **different scales**.
HS-LS2-1.2	SEP-DCI	**Use mathematical** and/or **computational representations** to support explanations of **factors** that affect **carrying capacity** of ecosystems.
HS-LS2-1.3	DCI-CCC	Apply knowledge of **factors** that affect **carrying capacity** to **ecosystems** at **different scales.**
HS-LS2-1.4	SEP-CCC	**Use mathematical** and/or **computational representations** to support explanations of a phenomenon at different scales.

Details and Clarifications

- **Use mathematical** and/or **computational representations** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
  - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems

- **Mathematical** and/or **computational representations** may include, but are NOT limited to:
  - graphs showing linear and/or exponential growth
  - a simulation showing changes for populations at different scales
  - data identifying changes in numbers and/or types of organisms over time

- **Factors** that affect **carrying capacity** may include, but are NOT limited to:
  - available living and/or nonliving resources (e.g., food, water)
  - challenges of predation, competition, disease
  - environmental conditions

- Examples of **ecosystems** at **different scales** may include, but are NOT limited to:
  - pond vs. ocean
  - a small area in a forest vs. a large forest ecosystem

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena or design solutions to support and revise explanations. **Connections to Nature of Science** **Scientific Knowledge is Open to Revision in Light of New Evidence** • Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.	**LS2.A: Interdependent Relationships in Ecosystems** • Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	**Scale, Proportion, and Quantity** • Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 64–67	pp. 150–152 pp. 154–156	pp. 89–91
NGSS Appendices	Appendix F p. 10 Appendix H p. 5	Appendix E p. 5	Appendix G pp. 6–7
Clarification Statement	Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.		
Assessment Boundary	Assessment is limited to provided data.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS2-2.1	SEP-DCI-CCC	**Use mathematical representations** to support and/or revise explanations about **factors** and/or **interactions** that affect **biodiversity** and/or **populations** in **ecosystems at different scales**.
HS-LS2-2.2	SEP-DCI	**Use mathematical representations** to support and/or revise explanations about **factors** and/or **interactions** that affect **biodiversity** and/or **populations** in an ecosystem.
HS-LS2-2.3	DCI-CCC	Connect **factors** and/or **interactions** to changes in **biodiversity** and/or **populations** in **ecosystems at different scales**.
HS-LS2-2.4	SEP-CCC	**Use mathematical representations** to support explanations of a phenomenon at different scales.

Details and Clarifications

- **Use mathematical representations** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
  - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems

- **Mathematical representations** may include, but are NOT limited to:
  - a graph showing changes to population sizes as a function of biotic and/or abiotic factors
  - a table showing numbers and/or types of organisms as a function of biotic and/or abiotic factors
  - a simulation showing interactions between ecosystems at different scales

- **Factors** and/or **interactions** that affect **biodiversity** and/or **populations** may include, but are NOT limited to:
  - availability of resources and/or habitat
  - presence of invasive species
  - changes in environmental conditions
  - changes in biotic and/or abiotic factors
  - interactions among organisms at different scales (e.g., plants and microbes)

- Examples of **ecosystems at different scales** may include, but are NOT limited to:
  - pond vs. ocean
  - a small area in a forest vs. a large forest ecosystem

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, and 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.

Connections to Nature of Science

Scientific Knowledge is Open to Revision in Light of New Evidence
• Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.</td><td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
• Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.</td><td>Energy and Matter
• Energy drives the cycling of matter within and between systems.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 67–71</td><td>pp. 152–154</td><td>pp. 94–96</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 11–12
Appendix H
p. 5</td><td>Appendix E
p. 5</td><td>Appendix G
pp. 8–9</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-LS2-3.1	SEP-DCI-CCC	**Construct** and/or **revise** an **explanation** based on **evidence** for the **cycling** of **matter** and/or **flow** of **energy** in **aerobic** and/or **anaerobic conditions**.
HS-LS2-3.2	SEP-DCI	**Construct** and/or **revise** an **explanation** based on **evidence** for **aerobic** and/or **anaerobic conditions**.
HS-LS2-3.3	DCI-CCC	Describe the **cycling** of **matter** and/or **flow** of **energy** in **aerobic** and/or **anaerobic conditions**.
HS-LS2-3.4	SEP-CCC	**Construct** and/or **revise** an **explanation** based on evidence for the cycling of matter and/or flow of energy in a system**.**

Details and Clarifications

- **Construct** and/or **revise** an **explanation** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- Examples of **evidence** for the **cycling** of **matter** and/or **flow** of **energy** during **aerobic** and/or **anaerobic conditions** include, but are NOT limited to:
  - organisms taking in matter and rearranging the atoms in chemical reactions
  - matter being rearranged and/or energy being released during cellular respiration
  - solar energy being captured and used during photosynthesis to produce glucose for cellular respiration

Performance Expectation	**HS-LS2-4** Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Using Mathematics and Computational Thinking Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena or design solutions to support claims.	**LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** • Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.	**Energy and Matter** • Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 64–67	pp. 152–154	pp. 94–96
NGSS Appendices	Appendix F p. 10	Appendix E p. 5	Appendix G pp. 8–9
Clarification Statement	Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.		
Assessment Boundary	Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS2-4.1	SEP-DCI-CCC	**Use mathematical representations** to support claims for the **cycling of matter** and/or **flow of energy** among organisms in an ecosystem.
HS-LS2-4.2	SEP-DCI	Due to strong overlap between the DCI and the CCC, items are not coded HS-LS2-4.2.
HS-LS2-4.3	DCI-CCC	Describe the **cycling of matter** and/or **flow of energy** among organisms in an ecosystem.
HS-LS2-4.4	SEP-CCC	**Use mathematical representations** to support claims for energy and/or matter conservations and/or transfer.

Details and Clarifications

- **Use mathematical representations** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
  - applying techniques of algebra and/or functions to represent and/or solve scientific and engineering problems

- Components of **mathematical representations** may include, but are NOT limited to:
  - relative numbers of organisms at various trophic levels of an ecosystem
  - relative amounts of matter and/or energy at various trophic levels of an ecosystem
  - direction of matter and/or energy flow between organisms and/or between organisms and the environment

- Examples of claims about the **cycling of matter** and/or **flow of energy** may include, but are NOT limited to:
  - There are more organisms at lower trophic levels than at higher trophic levels.
  - Matter and/or energy flows between organisms and their environment.
  - Organisms at the lowest trophic level in an ecosystem (e.g., producers) have higher total biomass than organisms at higher trophic levels (e.g., primary, secondary, and tertiary consumers).
  - Organisms at the lowest trophic level in an ecosystem (e.g., producers) have access to more energy than organisms at higher trophic levels (e.g., primary, secondary, and tertiary consumers).
  - A small fraction of the matter consumed at lower trophic levels is transferred to higher trophic levels.
  - Energy that is not transferred between trophic levels is used for growth, maintenance, and/or repair and/or transferred to the environment.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show how relationships among variables between systems and their components in the natural and designed worlds.
• Develop a model based on evidence to illustrate the relationships between systems or components of a system.</td><td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
• Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

PS3.D: Energy in Chemical Processes
• The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary)</td><td>Systems and System Models
• Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 56–59</td><td>pp. 152–154
pp. 128–130</td><td>pp. 91–94</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 6</td><td>Appendix E
pp. 5–8</td><td>Appendix G
pp. 7–8</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Examples of models could include simulations and mathematical models.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment does not include the specific chemical steps of photosynthesis and respiration.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-LS2-5.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** to illustrate the **role** of **photosynthesis** and/or **cellular respiration** in the **cycling of carbon** among **Earth systems.**
HS-LS2-5.2	SEP-DCI	**Develop** and/or **use** a **model** to illustrate the **role** of **photosynthesis** and/or **cellular respiration** in the **cycling of carbon.**
HS-LS2-5.3	DCI-CCC	Connect the **role** of **photosynthesis** and/or **cellular respiration** to the cycling of carbon among **Earth systems.**
HS-LS2-5.4	SEP-CCC	**Develop** and/or **use** a **model** to illustrate interactions within and/or between systems.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or to describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- **Models** may include, but are NOT limited to:
  - inputs and/or outputs of photosynthesis and/or cellular respiration

- **Earth systems** include:
  - biosphere
  - atmosphere
  - hydrosphere
  - geosphere

- Examples of the **role** of **photosynthesis** and/or **cellular respiration** in the **cycling of carbon** among **Earth systems** may include, but is NOT limited to:
  - photosynthesizing land organisms from the biosphere removing carbon dioxide from the atmosphere
  - photosynthesizing marine organisms from the biosphere removing dissolved carbon dioxide from the hydrosphere
  - organisms from the biosphere releasing carbon dioxide into the atmosphere/hydrosphere during cellular respiration
  - carbon dioxide gas transferring between the hydrosphere and the atmosphere

Performance Expectation	**HS-LS2-6** Evaluate 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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. **Connections to Nature of Science** **Scientific Knowledge is Open to Revision in Light of New Evidence** • Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 71–74	pp. 154–156	pp. 98–101
NGSS Appendices	Appendix F pp. 13–14 Appendix H p. 5	Appendix E p. 5	Appendix G pp. 10–11
Clarification Statement	Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.		
Assessment Boundary	An assessment boundary is not provided for this PE.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS2-6.1	SEP-DCI-CCC	**Evaluate** the claims, evidence, and/or reasoning behind currently accepted **explanations** of how the **complex interactions** within an ecosystem help maintain **stability** and/or cause **change**.
HS-LS2-6.2	SEP-DCI	**Evaluate** the claims, evidence, and/or reasoning behind currently accepted **explanations** about **complex interactions** within an ecosystem.
HS-LS2-6.3	DCI-CCC	Connect **complex interactions** within an ecosystem to **stability** and/or **change**.
HS-LS2-6.4	SEP-CCC	**Evaluate** the claims, evidence, and/or reasoning behind currently accepted **explanations** of how things change and/or how things remain stable.

Details and Clarifications

- **Evaluate** the claims, evidence, and/or reasoning behind currently accepted **explanations** is expanded to include:
  - describing criteria used to critique claims
  - using evidence to compare and/or evaluate competing arguments and/or solutions
  - using evidence to determine the merit of an argument and/or an explanation
  - using evidence to construct and/or support an argument and/or a claim
  - evaluating competing design solutions to real world problems using scientific ideas and/or evidence and/or relevant economic, societal, and/or environmental considerations.

- **Complex interactions** may include, but are NOT limited to:
  - relationships among different species
  - relationships between populations and their environment
  - biological disturbances and the effect on populations
  - physical disturbances and the effect on populations
  - resources affecting population size

- **Explanations** of **stability and change** may include, but are NOT limited to:
  - biological and/or physical disturbances can change the types and/or numbers of the ecosystem's species
  - ecosystems with modest disruptions maintain stable conditions or return to their original state after the disruption
  - extreme fluctuations in ecosystem conditions can change the resources and/or habitat availability to such a degree that the ecosystem cannot return to its original state and instead becomes a very different ecosystem
  - feedback can stabilize or destabilize an ecosystem

Performance Expectation	**HS-LS2-7** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.		
	Science & Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Dimensions	**Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** • Moreover, anthropogenic changes (induced by human activity) in the environment — including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change — can disrupt an ecosystem and threaten the survival of some species. **LS4.D: Biodiversity and Humans** • Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). *(secondary)* • Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. *(secondary) (Note: This Disciplinary Core Idea is also addressed by HS-LS4-6.)* **ETS1.B: Developing Possible Solutions** • When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. *(secondary)*	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 67–71	pp. 154–156 pp. 166–167 pp. 206–208	pp. 98–101
NGSS Appendices	Appendix F pp. 11–12	Appendix E pp. 5–6 Appendix I pp. 1–7	Appendix G pp. 10–11
Clarification Statement	Examples of human activities can include urbanization, building dams, and dissemination of invasive species.		
Assessment Boundary	An assessment boundary is not provided for this PE.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS2-7.1	SEP-DCI-CCC	**Design**, **evaluate**, and/or **refine** a **solution** for reducing **changes** to the **environment** and/or to **biodiversity** due to **impacts** of **human activities**.
HS-LS2-7.2	SEP-DCI	**Design**, **evaluate**, and/or **refine** a **solution** for the **impacts** of **human activities** to the **environment** and/or to **biodiversity**.
HS-LS2-7.3	DCI-CCC	Connect **impacts** of **human activity** to **changes** to the **environment** and/or to **biodiversity**.
HS-LS2-7.4	SEP-CCC	**Design**, **evaluate**, and/or **refine** a **solution** that reduces changes in a system.

Details and Clarifications

- **Design**, **evaluate**, and/or **refine** a **solution** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- **Impacts** of **human activities** may include, but are NOT limited to:
  - overpopulation
  - deforestation
  - burning fossil fuels
  - dumping garbage in oceans
  - introduction of invasive species
  - extraction of resources

- **Changes** to the **environment** and/or to **biodiversity** may include, but are NOT limited to:
  - habitat destruction
  - global warming
  - poor air and/or water quality
  - ocean acidification
  - shifts in the types and/or numbers of organisms in an ecosystem
  - reduction, extinction, formation, and/or migration of species

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-8 Evaluate the evidence for the role of group behavior on individual and species’ chances to survive and reproduce.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
• Evaluate the evidence behind currently accepted explanations to determine the merits of arguments.

Connections to Nature of Science

Scientific Knowledge is Open to Revision in Light of New Evidence
• Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.</td><td>LS2.D: Social Interactions and Group Behavior
• Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 71–74</td><td>pp. 156–157</td><td>pp. 87–89</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 13–14
Appendix H
p. 5</td><td>Appendix E
p. 5</td><td>Appendix G
pp. 5–6</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-LS2-8.1	SEP-DCI-CCC	**Evaluate** the **claims**, **evidence**, and/or **reasoning** about **cause and effect** relationships between **group behavior** and an individual's and/or a species' chances to **survive** and/or **reproduce**.
HS-LS2-8.2	SEP-DCI	**Evaluate** the **claims**, **evidence**, and/or **reasoning** about **group behavior** and/or an individual's and/or a species' chances to **survive** and/or **reproduce**.
HS-LS2-8.3	DCI-CCC	Use **cause and effect** relationships to connect **group behavior** to an individual and/or species' chances to **survive** and/or **reproduce**.
HS-LS2-8.4	SEP-CCC	**Evaluate** the **claims**, **evidence**, and/or **reasoning** behind cause and effect relationships.

Details and Clarifications

- **Evaluate** the **claims**, **evidence,** and/or **reasoning** is expanded to include:
  - describing criteria used to critique claims
  - using evidence to compare and/or evaluate competing arguments and/or solutions
  - using evidence to determine the merit of an argument and/or an explanation
  - using evidence to construct and/or support an argument and/or a claim
  - evaluating competing design solutions to real-world problems using scientific ideas and/or evidence and/or relevant economic, societal, and/or environmental considerations

- Examples of **group behavior** may include, but are NOT limited to:
  - flocking
  - schooling
  - herding
  - cooperative hunting
  - swarming

- Examples of **cause and effect** relationships between **group behavior** and an individual's and/or a species' chances to **survive** and/or **reproduce** may include, but are NOT limited to:
  - group behavior increasing the effective vigilance of an individual
  - group behavior confusing and/or intimidating predators
  - group behavior providing cover where none exists
  - group behavior increasing feeding opportunities
  - group behavior aiding navigation
  - group behavior increasing access to mates
  - group behavior helping in the finding of food

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Asking Questions and Defining Problems Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Ask questions that arise from examining models or a theory to clarify relationships.	**LS1.A: Structure and Function** • All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. *(secondary) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)* **LS3.A: Inheritance of Traits** • Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 54–56	pp. 143–145 pp. 158–159	pp. 87–89
NGSS Appendices	Appendix F p. 4	Appendix E p. 4 Appendix E p. 6	Appendix G p. 5
Clarification Statement	A clarification statement is not provided for this PE.		
Assessment Boundary	Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS3-1.1	SEP-DCI-CCC	**Ask questions** to clarify **cause and effect** relationships about the role of **DNA** and/or **chromosomes** in coding the instructions for characteristic **traits** passed from parents to offspring.
HS-LS3-1.2	SEP-DCI	**Ask questions** to clarify the role of **DNA** and/or **chromosomes** in coding the instructions for characteristic **traits** passed from parents to offspring.
HS-LS3-1.3	DCI-CCC	Use **cause and effect** relationships to connect **DNA** and/or **chromosomes** to characteristic **traits** passed from parents to offspring.
HS-LS3-1.4	SEP-CCC	**Ask questions** to clarify cause and effect relationships.

Details and Clarifications

- **Ask questions** is expanded to include:
  - asking and/or identifying questions that arise from observation and/or investigation to seek additional information
  - asking questions to determine quantitative and/or qualitative relationships, between independent and dependent variables.
  - asking questions to refine a model, an explanation, and/or an engineering problem.
  - asking questions to determine if a question is testable and/or relevant.
  - asking questions that frame a hypothesis based on observations and/or scientific principles.
  - asking questions that challenge an argument, data set and/or design.
  - defining a design problem that involves the development of a process and/or system with interacting components
  - describing social, technical, and/or environmental criteria for a successful solution
  - describing social, technical, and/or environmental constraints that could limit the success of a solution

- Examples of the roles of **DNA** and/or **chromosomes** in coding the instructions for characteristic **traits** may include, but are NOT limited to:
  - each chromosome pair in a cell contains two variants of each gene
  - DNA contains instructions that code for specific proteins that result in an organism's traits
  - mutations to genes and/or chromosomes can result in changes to proteins, resulting in changes to an organism's traits
  - not all sections of DNA on a chromosome code for inherited traits
  - the cells of an organism express different inherited traits as a result of expressing different genes

- Evidence of **cause and effect** relationships may include, but is NOT limited to:
  - the effects of cell types on the type of proteins produced by a cell
  - the effects of a genetic mutation on the type of protein produced and/or trait expressed
  - the effects of DNA and/or gene sequence on the type of protein produced and/or trait expressed

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated evidence.	**LS3.B: Variation of Traits** • In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 71–74	pp. 160–161	pp. 87–89
NGSS Appendices	Appendix F pp. 13–14	Appendix E p. 6	Appendix G pp. 5–6
Clarification Statement	Emphasis is on using data to support arguments for the way variation occurs.		
Assessment Boundary	Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS3-2.1	SEP-DCI-CCC	**Make** and/or **defend** a **claim** based on evidence about **cause and effect** relationships between **inheritable genetic variations** and: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
HS-LS3-2.2	SEP-DCI	**Make** and/or **defend** a **claim** based on evidence about **inheritable genetic variations** and/or (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
HS-LS3-2.3	DCI-CCC	Use **cause and effect** relationships to connect **inheritable genetic variations** to: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
HS-LS3-2.4	SEP-CCC	**Make** and/or **defend** a **claim** based on evidence about cause and effect relationships.

Details and Clarifications

- **Make** and/or **defend** a **claim** is expanded to include**:**
  - describing criteria used to critique claims
  - using evidence to compare and/or evaluate competing arguments and/or solutions
  - using evidence to determine the merit of an argument and/or an explanation
  - using evidence to construct and/or support an argument and/or a claim
  - evaluating competing design solutions to real-world problems using scientific ideas and/or evidence and/or relevant economic, societal, and/or environmental considerations

- Examples of **cause and effect** relationships that may result in **inheritable genetic variations** may include, but are NOT limited to:
  - chromosome pairs exchanging during meiosis resulting in unique gene combinations
  - genetic mutations occurring when an incorrect base pair substitution remains uncorrected during replication
  - environmental factors (e.g., UV radiation, preservatives in food, viruses) causing changes to DNA molecules, resulting in mutations
  - genetic material and/or mutations being inherited by offspring

Performance Expectation	**HS-LS3-3** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.		
	Science & Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Dimensions	**Analyzing and Interpreting Data** Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • 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.	**LS3.B: Variation of Traits** • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Scale, Proportion, and Quantity** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). **Connections to Nature of Science** **Science is a Human Endeavor** • Technological advances have influenced the progress of science and science has influenced advances in technology. • Science and engineering are influenced by society and society is influenced by science and engineering.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 61–63	pp. 160–161	pp. 89–91
NGSS Appendices	Appendix F p. 9	Appendix E p. 6	Appendix G pp. 6-7 Appendix H p.6
Clarification Statement	Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.		
Assessment Boundary	Assessment does not include Hardy-Weinberg calculations.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS3-3.1	SEP-DCI-CCC	**Apply concepts** of **statistics** and/or **probability** to describe and/or predict the **effects** of **environmental** and/or **genetic factors** on the variation and/or distribution of **expressed traits** in a population.
HS-LS3-3.2	SEP-DCI	Due to a strong overlap between the DCI and the CCC, items are not coded HS-LS3-3.2.
HS-LS3-3.3	DCI-CCC	Connect the variation and/or distribution of **expressed traits** in a population to **environmental** and/or **genetic factors**.
HS-LS3-3.4	SEP-CCC	**Apply concepts** of statistics and probability to examine scientific data and/or predict the effect of a change in one variable on another.

Details and Clarifications

- **Apply concepts** of **statistics** and/or **probability** is expanded to include:
  - organizing and/or interpreting data using tables, graphs, and/or statistical analysis
  - identifying relationships in data using tables and/or graphs
  - identifying limitations (e.g., measurement error, sample selection) in data
  - comparing the consistency in measurements and/or observations in sets of data
  - using analyzed data to support a claim and/or an explanation

- **Environmental factors** may include, but are NOT limited to:
  - availability of resources (e.g., light, water, food, space)
  - weather (e.g., average temperature, precipitation)
  - chemicals

- **Genetic factors** may include, but are NOT limited to:
  - mutation
  - inheriting genes from parents
  - crossing over during meiosis

- **Expressed traits** may include, but are NOT limited to:
  - characteristics related to the development of an individual
  - characteristics related to appearance
  - behavior
  - likelihood of producing offspring

- **Effects** of **factors** on **traits** may include, but are NOT limited to:
  - a causative relationship between factor and trait
  - a change in frequency, distribution, and/or variation of expressed trait

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.
• Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
• A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.</td><td>LS4.A: Evidence of Common Ancestry and Diversity
• Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
• Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 74–77</td><td>pp. 162–163</td><td>pp. 85–87</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 15
Appendix H
p. 5</td><td>Appendix E
p. 6</td><td>Appendix G
pp. 3–5
Appendix H
p. 6</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-LS4-1.1	SEP-DCI-CCC	**Communicate** scientific **information** that common ancestry and/or biological evolution are supported by **patterns** observed in **DNA**, **amino acid sequences**, **anatomical evidence**, and/or **embryological evidence**.
HS-LS4-1.2	SEP-DCI	**Communicate** scientific **information** that common ancestry and/or biological evolution are supported by **DNA**, **amino acid sequences**, **anatomical evidence**, and/or **embryological evidence**.
HS-LS4-1.3	DCI-CCC	Use **patterns** from **DNA, amino acid sequences, anatomical,** and/or **embryological evidence** to provide evidence of **evolution**.
HS-LS4-1.4	SEP-CCC	**Communicate** scientific **information** about phenomena that are supported by patterns in evidence.

Details and Clarifications

- **Communicate** scientific **information** is expanded to include:
    - identifying scientific and/or technical evidence, concepts, processes, and/or information
    - evaluating the validity and/or reliability of claims from different sources
    - integrating multiple sources of information to construct and/or support an explanation
    - summarizing complex information

- **Information** formats may include, but are NOT limited to:
    - text
    - diagrams
    - graphs
    - tables
    - models
    - animations
    - equations

- **Patterns** in **DNA** that can be used to provide evidence of **evolution** may include, but are NOT limited to:
    - similarities in the DNA sequences of different species
    - similarities in DNA sequences between species with a common ancestor

- **Patterns** in **amino acid sequences** that can be used to provide evidence of **evolution** may include, but are NOT limited to:
    - similarities in the pattern of amino acid sequences across different species
    - overlaps in amino acid sequences even when DNA sequences are different

- **Patterns** in **anatomical and embryological evidence** that can be used to provide evidence of **evolution** may include, but are NOT limited to:
    - analogous structures between different species in the fossil record
    - progressive anatomical changes across species preserved in the fossil record
    - anatomical similarities and differences between organisms living today and organisms in the fossil record
    - embryological similarities between species at various stages of development

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
• Construct 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.</td><td>LS4.B: Natural Selection
• Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information — that is, trait variation — that leads to differences in performance among individuals.

LS4.C: Adaptation
• Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment’s limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 67–71</td><td>pp. 163–164
pp. 164–166</td><td>pp. 87–89</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 11–12</td><td>Appendix E
p. 6</td><td>Appendix G
pp. 5–6</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on using evidence to explain the influence each of the four factors has on the number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-LS4-2.1	SEP-DCI-CCC	**Construct** an **explanation** based on **evidence** that the process of **evolution** is primarily the **result** of **interactions** among: **(1)** the potential for a species to increase in number, **(2)** the heritable genetic variation of individuals in a species due to mutation and/or sexual reproduction, **(3)** competition for limited resources, and/or **(4)** the proliferation of those organisms that are better able to survive and/or reproduce in the environment.
HS-LS4-2.2	SEP-DCI	**Construct** an **explanation** based on **evidence** that the process of **evolution** includes: **(1)** the potential for a species to increase in number, **(2)** the heritable genetic variation of individuals in a species due to mutation and/or sexual reproduction, **(3)** competition for limited resources, and/or **(4)** the proliferation of those organisms that are better able to survive and/or reproduce in the environment.
HS-LS4-2.3	DCI-CCC	Connect the process of **evolution** to the **results** of **interactions** among: **(1)** the potential for a species to increase in number, **(2)** the heritable genetic variation of individuals in a species due to mutation and/or sexual reproduction, **(3)** competition for limited resources, and/or **(4)** the proliferation of those organisms that are better able to survive and/or reproduce in the environment.
HS-LS4-2.4	SEP-CCC	**Construct** an **explanation** based on evidence for cause and effect relationships in a system.

Details and Clarifications

- **Construct** an **explanation** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- Types of **evidence** that the process of **evolution** is primarily the **result** of **interactions** among **(1), (2), (3)** and/or **(4)** include, but are NOT limited to:
  - An increase in population size results in an increase in competition for limited resources.
  - Mutations can result in a competitive advantage relative to other individuals in a species.
  - Individuals with traits that give a competitive advantage survive and/or reproduce at higher rates.
  - Individuals that survive and/or reproduce at higher rates provide a greater proportion of their genetic variations in the next generation.
  - Individuals with traits that enable them to survive and/or reproduce in distinct environments using distinct resources can evolve into unique species over time.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
• 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.</td><td>LS4.B: Natural Selection
• Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.
• The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

LS4.C: Adaptation
• Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
• Adaptation also means that the distribution of traits in a population can change when conditions change.</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 61–63</td><td>pp. 163–164
pp. 164–166</td><td>pp. 85–87</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 9</td><td>Appendix E
p. 6</td><td>Appendix G
pp. 3–5</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-LS4-3.1	SEP-DCI-CCC	**Apply concepts** of **statistics** and/or **probability** to analyze **patterns** that support **explanations** that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
HS-LS4-3.2	SEP-DCI	**Apply concepts** of **statistics** and/or **probability** to support **explanations** that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
HS-LS4-3.3	DCI-CCC	Use **patterns** to support **explanations** that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
HS-LS4-3.4	SEP-CCC	**Apply concepts** of **statistics** and/or **probability** to observe patterns that support explanations.

Details and Clarifications

- **Apply concepts** of **statistics** and/or **probability** is expanded to include:
  - organizing and/or interpreting data, using tables, graphs, and/or statistical analysis
  - identifying relationships in data, using tables and/or graphs
  - identifying limitations (e.g., measurement error, sample selection) in data
  - comparing the consistency in measurements and/or observations in sets of data
  - using analyzed data to support a claim and/or an explanation

- **Patterns** that support explanations may include, but are NOT limited to:
  - changes in the frequency of a particular heritable trait over time
  - beneficial traits are more common in a population than harmful traits
  - changes in the distribution of adaptations (e.g., anatomical, behavioral, physiological)
  - variation in trait expression within a population
  - traits that positively affect survival becoming more common in a population
  - traits that negatively affect survival becoming less common in a population
  - changes in the distribution of alleles over time as the environment changes
  - changes in reproductive success over time across populations with or without a specific heritable trait

- **Explanations** may include, but are NOT limited to:
  - a description of how the expression of a trait affects the survival and/or reproduction of individuals
  - a description of how natural selection affects the distribution of a heritable trait over time
  - a description of how the distribution of adaptations change in a population over time

<table>
<tr><th>Performance Expectation</th><th colspan="3">HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.</th></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
• Construct 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.</td><td>LS4.C: Adaptation
• Natural selection leads to adaptation that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
• Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 67–71</td><td>pp. 164–166</td><td>pp. 87–89</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 11–12</td><td>Appendix E
p. 6</td><td>Appendix G
pp. 5–6
Appendix H
p. 6</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-LS4-4.1	SEP-DCI-CCC	**Construct** an **explanation** based on **evidence** for the **cause and effect** relationships between **natural selection** and the **adaptation of populations**.
HS-LS4-4.2	SEP-DCI	**Construct** an **explanation** based on **evidence** for **natural selection** and/or the **adaptation of populations**.
HS-LS4-4.3	DCI-CCC	Use **cause and effect** relationships to connect **natural selection** to the **adaptation of populations**.
HS-LS4-4.4	SEP-CCC	**Construct** an **explanation** based on evidence for cause and effect relationships in a system.

Details and Clarifications

- **Construct** an **explanation** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- **Evidence** may include, but is NOT limited to:
  - differences in temperature range, climate change, acidity, light, geographic barriers, and/or evolution of other organisms
  - change in gene frequency and/or distribution of traits over time
  - rate of survival and/or reproduction of organisms over generations

- **Cause and effect** relationships between **natural selection** and the **adaptation of populations** may include, but are NOT limited to:
  - changes in the abiotic factors of an ecosystem (e.g., seasonal temperature ranges, climate change, acidity, light, water, nutrients, shelter, geographic barriers) causing changes in gene frequency and/or the distribution of traits over time
  - changes in the biotic factors of an ecosystem (e.g., new species, predators, disease, competitors, prey, mating partners) causing changes in reproduction and/or survival rates over time

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science. • Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.	**LS4.C: Adaptation** • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. • Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 71–74	pp. 164–166	pp. 87–89
NGSS Appendices	Appendix F pp. 13–14	Appendix E p. 6	Appendix G pp. 5–6
Clarification Statement	Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.		
Assessment Boundary	An assessment boundary is not provided for this PE.		

Items may ask students to:

Code	Alignment	Item Specification
HS-LS4-5.1	SEP-DCI-CCC	**Evaluate** the **evidence** from **cause and effect** relationships to make and/or support 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/or (3) the extinction of other species.
HS-LS4-5.2	SEP-DCI	**Evaluate evidence** to make and/or support 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/or (3) the extinction of other species.
HS-LS4-5.3	DCI-CCC	Use **cause and effect** relationships to make and/or support 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/or (3) the extinction of other species.
HS-LS4-5.4	SEP-CCC	**Evaluate** the **evidence** from cause and effect relationships to make and/or support claims.

Details and Clarifications

- **Evaluate** the **evidence** is expanded to include:
  - describing criteria used to critique claims
  - using evidence to compare and/or evaluate competing arguments and/or solutions
  - using evidence to determine the merit of an argument and/or an explanation
  - using evidence to construct and/or support an argument and/or a claim
  - evaluating competing design solutions to real world problems using scientific ideas and/or evidence and/or relevant economic, societal, and/or environmental considerations.

- **Cause and effect** relationships may include, but are NOT limited to:
  - increase and/or decrease in the number of individuals of a species due to a change (e.g., loss of habitat, introduction of a disease)
  - extinction of a species due to a changing environment over time (e.g., pollution, habitat destruction, volcanic eruption)
  - emergence of a new species due to geographic isolation

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS4-6 Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Using Mathematics and Computational Thinking
Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
• Create or revise a simulation of a phenomenon, designed device, process, or system.</td><td>LS4.C: Adaptation
• Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline — and sometimes the extinction — of some species.

LS4.D: Biodiversity and Humans
• Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (Note: This Disciplinary Core Idea is also addressed by HS-LS2-7.)

ETS1.B: Developing Possible Solutions
• When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary)
• Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (secondary)</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 64–67</td><td>pp. 164–166
pp. 166–167
pp. 206–208</td><td>pp. 87–89</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 10</td><td>Appendix E
p. 6
Appendix I
pp. 1–7</td><td>Appendix G
pp. 5–6</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-LS4-6.1	SEP-DCI-CCC	**Create** and/or **revise a simulation** to test a solution that mitigates **adverse impacts** of **human activity** on **biodiversity**.
HS-LS4-6.2	SEP-DCI	**Create** and/or **revise a simulation** that models **human activity** and/or **biodiversity.**
HS-LS4-6.3	DCI-CCC	Use **cause and effect** relationships to connect **human activity** to its **adverse impacts** on **biodiversity**.
HS-LS4-6.4	SEP-CCC	**Create** and/or **revise a simulation** to test cause and effect relationships in a system.

Details and Clarifications

- **Create** and/or **revise a simulation** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
  - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems

- **Simulations** may include, but are NOT limited to:
  - inputs that take cost, safety, reliability, cultural constraints, and/or environmental constraints into account
  - advantages and/or disadvantages of a solution
  - information about human activities
  - information about the effects of human activities on biodiversity
  - information about the outcomes of a solution

- Examples of the **adverse impacts** of **human activity** on **biodiversity** may include, but are NOT limited to:
  - overpopulation of humans leading to loss of habitat and/or a decrease in the number of species in a particular habitat
  - an increase in atmospheric CO2 concentrations resulting in an increase in the number of endangered species in the Arctic
  - pollution of a local stream leading to a decrease in genetic variation in a fish population

Earth and Space Sciences

Disciplinary Core Ideas:

- ESS1 Earth's Place in the Universe
- ESS2 Earth's Systems
- ESS3 Earth and Human Activity

<table>
<tr><td>Performance Expectation</td><td colspan="3">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 in the form of radiation.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>ESS1.A: The Universe and Its Stars
• The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.

PS3.D: Energy in Chemical Processes and Everyday Life
• Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary)</td><td>Scale, Proportion, and Quantity
• The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 56–59</td><td>pp. 173–174
pp. 128–130</td><td>pp. 89–91</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 6</td><td>Appendix E
p. 2
Appendix E
p. 8</td><td>Appendix G
pp. 6–7</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun’s core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun’s radiation varies due to sudden solar flares (“space weather”), the 11-year sunspot cycle, and non-cyclic variations over centuries.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment does not include details of the atomic and sub-atomic processes involved with the sun’s nuclear fusion.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS1-1.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** based on **evidence** of **scale**, **proportion**, and/or **quantity** to illustrate the **lifespan** of the **sun** and/or the role of **nuclear fusion** in the sun's core to release energy in the form of **radiation**.
HS-ESS1-1.2	SEP-DCI	**Develop** and/or **use** a **model** to illustrate the **lifespan** of the **sun** and/or the **role** of **nuclear fusion** in the sun's core to release energy in the form of **radiation**.
HS-ESS1-1.3	DCI-CCC	**Use** concepts of **scale**, **proportion**, and/or **quantity** to illustrate the **lifespan** of the **sun** and/or the **role** of **nuclear fusion** in the sun's core to release energy in the form of **radiation**.
HS-ESS1-1.4	SEP-CCC	**Develop** and/or **use** a **model** to illustrate scale, proportion, and/or quantity relationships in a system.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or to describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- **Models** may include, but are NOT limited to:
  - the process by which the sun releases energy
  - the process by which solar radiation reaches Earth
  - the mass and/or lifespan of the sun in relation to the masses and/or lifespans of other stars
  - events associated with variations in solar radiation (e.g., solar flares, sunspots)
  - rate at which nuclear fusion in the sun uses hydrogen fuel
  - rate at which nuclear fusion in the sun releases helium and/or energy

- Examples of using **scale, proportion,** and**/**or **quantity** to illustrate the **lifespan** of the **sun** may include, but are NOT limited to:
  - the size and/or brightness of a star changing with the relative proportion of hydrogen to helium
  - a star's lifespan depending on an initial quantity of fuel

- Examples of using **scale, proportion,** and/or **quantity** to illustrate how **nuclear fusion** releases **energy** in the form of **radiation** may include, but are NOT limited to:
  - fusion releasing a significantly larger amount of energy than chemical reactions do
  - solar flares temporarily changing the sun's energy production

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, 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. **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.	**ESS1.A: The Universe and Its Stars** • The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. • The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. • Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. **PS4.B: Electromagnetic Radiation** • Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. *(secondary)*	**Energy and Matter** • Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems. **Connections to Engineering, Technology, and Applications of Science** **Interdependence of Science, Engineering, and Technology** • Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise **Connections to Nature of Science** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. • Science assumes the universe is a vast single system in which basic laws are consistent.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 67–71	pp. 173–174 pp. 133–136	pp. 94–96 pp. 210–214
NGSS Appendices	Appendix F pp. 11–12 Appendix H p. 6	Appendix E p. 2 Appendix E p. 8	Appendix G pp. 8–9 Appendix J p. 3 Appendix H p. 6
Clarification Statement	Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).		
Assessment Boundary	An assessment boundary is not provided for this PE.		

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS1-2.1	SEP-DCI-CCC	**Construct** an **explanation** of the **Big Bang theory** based on astronomical **evidence** of **light spectra, motion of distant galaxies,** and/or **composition of matter in the universe**.
HS-ESS1-2.2	SEP-DCI	Due to a strong overlap between the CCC and DCI, items are not coded HS-ESS1-2.2
HS-ESS1-2.3	DCI-CCC	Connect **light spectra, motion of distant galaxies,** and/or **composition of matter in the universe** to the **Big Bang theory**.
HS-ESS1-2.4	SEP-CCC	**Construct** an **explanation** about energy flowing and/or matter cycling into, out of, or within a system.

Details and Clarifications

- **Construct** an **explanation** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- Types of **evidence** of **light spectra, motion of distant galaxies,** and/or **composition of matter in the universe** may include, but are NOT limited to:
  - light intensity varying over a range of wavelengths
  - amount and/or ratio of hydrogen, helium, and/or heavier elements in stars
  - sequence of stars in developmental stages
  - atoms of an element emitting and/or absorbing characteristic frequencies of light
  - objects emitting a spectrum of electromagnetic radiation that depends on the object's temperature
  - cosmic microwave background radiation

- An **explanation** of the **Big Bang theory** may include, but is NOT limited to:
  - The redshift vs. distance relationship is evidence that the universe is expanding.
  - Cosmic microwave background radiation and/or the ratio of hydrogen to helium have been shown to be consistent with a universe that was very dense and hot a long time ago and/or evolved through different stages as it expanded and cooled.
  - An expanding universe must have been smaller in the past and can be extrapolated back in time to a tiny size from which it expanded.

Performance Expectation	**HS-ESS1-3** Communicate scientific ideas about the way stars, over their life cycle, produce elements.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate scientific 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 (including orally, graphically, textually, and mathematically).	**ESS1.A: The Universe and Its Stars** • The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. • Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.	**Energy and Matter** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 74–77	pp. 173–174	pp. 94–96
NGSS Appendices	Appendix F p. 15	Appendix E p. 2	Appendix G pp. 8–9
Clarification Statement	Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.		
Assessment Boundary	Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.		

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS1-3.1	SEP-DCI-CCC	**Communicate scientific ideas** about the way **stars**, over their **life cycles**, use **nuclear processes** to produce **elements**.
HS-ESS1-3.2	SEP-DCI	**Communicate scientific ideas** about the way **stars** change over their **life cycle**s.
HS-ESS1-3.3	DCI-CCC	**Connect** the way **stars** produce **elements** to **nuclear processes**.
HS-ESS1-3.4	SEP-CCC	**Communicate scientific ideas** about changes in energy and/or matter in a system.

Details and Clarifications

- **Communicate scientific ideas** is expanded to include:
    - identifying scientific and/or technical evidence, concepts, processes, and/or information
    - evaluating the validity and/or reliability of claims from different sources
    - integrating multiple sources of information to construct and/or support an explanation
    - summarizing complex information

- **Information** formats may include, but are NOT limited to:
    - text
    - diagrams
    - graphs
    - tables
    - models
    - animations
    - equations

- Examples of the way **stars**, over their **life cycle**, use **nuclear processes** to produce **elements** may include, but are NOT limited to:
    - Nuclear fusion produces atomic nuclei lighter than and including iron.
    - Supernova explosions of massive stars produce elements heavier than iron.
    - Nuclear fusion releases energy.
    - Nuclear fusion processes within a star can change over time.
    - The total number of protons plus neutrons stays the same during nuclear fusion.
    - The mass and/or stage of development of a star is correlated to the types of elements it can produce during its lifetime.

Performance Expectation	**HS-ESS1-4** Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Using Mathematical and Computational Thinking Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric function ns, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical or computational representations of phenomena to describe explanations.	**ESS1.B: Earth and the Solar System** • Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.	**Scale, Proportion, and Quantity** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). **Connections to Engineering, Technology, and Applications of Science** **Interdependence of Science, Engineering, and Technology** • Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 64–67	pp. 175–176	pp. 89–91 pp. 210–214
NGSS Appendices	Appendix F p. 10	Appendix E p. 2	Appendix G pp. 6–7 Appendix J p. 3
Clarification Statement	Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.		
Assessment Boundary	Mathematical representations for the gravitational attraction of bodies and Kepler's laws of orbital motions should not deal with more than two bodies, nor involve calculus.		

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS1-4.1	SEP-DCI-CCC	**Use mathematical** and/or **computational representations** and **scale**, **proportion**, and/or **quantity** relationships to describe and/or predict the **motion** of **orbiting objects** in the solar system.
HS-ESS1-4.2	SEP-DCI	**Use mathematical** and/or **computational representations** to describe the **motion** of **orbiting objects** in the solar system.
HS-ESS1-4.3	DCI-CCC	Use **scale**, **proportion**, and/or **quantity** relationships to describe and/or predict the **motion** of **orbiting objects** in the solar system.
HS-ESS1-4.4	SEP-CCC	**Use mathematical** and/or **computational representations** to describe scale, proportion, and/or quantity relationships in a system.

Details and Clarifications

- **Use mathematical** and/or **computational representations** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
  - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems

- **Mathematical** and/or **computational representations** may include, but are NOT limited to:
  - Kepler's first law of planetary motion: $e = f/d$; where *e* is eccentricity, *f* is the distance between foci of an ellipse, and *d* is the ellipse's major axis length
  - Kepler's second law of planetary motion
  - Kepler's third law of planetary motion: T^2 is proportional to R^3; where *T* is the orbital period and *R* is the semi-major axis of the orbit
  - Newton's law of gravitation: $F_g = -G\frac{m_1 m_2}{d^2}$; where F_g is gravitational force, G is the universal gravitation constant, m_1 and m_2 are masses for two objects, and d is the distance between the two objects.
  - Newton's third law of motion

- Examples of using **scale**, **proportion** and/or **quantity** relationships to describe and/or predict the **motion** of **orbiting objects** in the solar system may include, but are NOT limited to:
  - describing and/or predicting a relationship among the trajectories of orbiting bodies
  - describing and/or predicting a relationship in the distance between a planet and its star
  - describing and/or predicting a relationship in the distance between an orbiting body and its orbital velocity
  - describing and/or predicting a relationship in the distance between an orbiting body and its orbital period
  - describing and/or predicting a relationship in the acceleration of a planet toward the sun, its distance from the sun, and/or its observed orbits

Note: The equations for Kepler's first and third laws as well as Newton's law of gravitation will be provided on the WCAS.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
• Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.</td><td>ESS1.C: The History of Planet Earth
• Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.

ESS2.B: Plate Tectonics and Large-Scale System Interactions
• Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth’s surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) (secondary)

PS1.C: Nuclear Processes
• Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (secondary)</td><td>Patterns
• Empirical evidence is needed to identify patterns.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 71–74</td><td>pp. 177–179
pp. 182–183
pp. 111–113</td><td>pp. 85–87</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 13–14</td><td>Appendix E
p. 2
Appendix E
p. 7</td><td>Appendix G
pp. 3–5</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages of oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate (a result of past plate interactions).</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS1-5.1	SEP-DCI-CCC	**Evaluate patterns** in **evidence** of the past and current **movements** of **continental** and/or **oceanic crust** and/or **evaluate** the theory of **plate tectonics** to explain the **ages** of **crustal rocks**.
HS-ESS1-5.2	SEP-DCI	**Evaluate evidence** of the past and current **movements** of **continental** and/or **oceanic crust** and/or **evaluate** the theory of **plate tectonics** to explain the **ages** of **crustal rocks**.
HS-ESS1-5.3	DCI-CCC	Connect **patterns** of past and current **movements** of **continental** and/or **oceanic crust** and/or the **theory of plate tectonics** to the **ages** of **crustal rocks**.
HS-ESS1-5.4	SEP-CCC	**Evaluate** patterns in **evidence** to explain a phenomenon.

Details and Clarifications

- **Evaluate** the **evidence** is expanded to include**:**
  - describing criteria used to critique claims
  - using evidence to compare and/or evaluate competing arguments and/or solutions
  - using evidence to determine the merit of an argument and/or an explanation
  - using evidence to construct and/or support an argument and/or a claim
  - evaluating competing design solutions to real world problems using scientific ideas and/or evidence and/or relevant economic, societal, and/or environmental considerations

- **Patterns** in **evidence** of the past and current **movements** of **continental** and/or **oceanic crust** may include, but are NOT limited to:
  - continental crust being older than oceanic crust
  - oldest continental rocks being located at the center of continents and rock age decreasing from center to margin
  - oceanic crust being oldest nearest the continents and rock age decreasing with proximity to mid-ocean ridges

- **Patterns** in **evidence** of **plate tectonics** may include, but are NOT limited to:
  - locations of volcanoes and/or earthquakes
  - shapes of continents
  - locations of mountains and fossils
  - formation of new rocks where magma rises as plates move apart
  - magnetic patterns in undersea rocks aligning with changes to Earth’s magnetic axis
  - warping of land under loads (e.g., lakes, ice sheets) showing that solid mantle’s rocks bend and flow

- Types of **evidence** supporting the **ages** of **crustal rocks** may include, but are NOT limited to:
  - ratio of parent to daughter atoms produced during radioactive decay
  - ratio of isotopes present

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
• Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
• A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.
• Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory.</td><td>ESS1.C: The History of Planet Earth
• Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth’s formation and early history.

PS1.C: Nuclear Processes
• Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (secondary)</td><td>Stability and Change
• Much of science deals with constructing explanations of how things change and how they remain stable.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 67–71</td><td>pp. 177–179
pp. 111–113</td><td>pp. 98–101</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 11–12
Appendix H
p. 6</td><td>Appendix E
p. 2
Appendix E
p. 7</td><td>Appendix G
pp. 10–11</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth’s oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS1-6.1	SEP-DCI-CCC	**Apply scientific reasoning** and/or **evidence** from ancient Earth materials, meteorites, other planetary surfaces, geologic processes**,** and/or radioactive decay to **construct** an **explanation** of **changes during Earth's formation** and/or **early history**.
HS-ESS1-6.2	SEP-DCI	**Apply scientific reasoning** and/or **evidence** from ancient Earth materials, meteorites, other planetary surfaces, geologic processes**,** and/or radioactive decay to **construct** an **explanation** of **Earth's formation** and/or **early history**.
HS-ESS1-6.3	DCI-CCC	Connect **changes** to ancient Earth materials, meteorites, other planetary surfaces, and/or **geologic processes** to **Earth's formation** and/or **early history**.
HS-ESS1-6.4	SEP-CCC	**Apply scientific reasoning** and/or **evidence** to **construct** an **explanation** for how things change and/or how they remain stable.

Details and Clarifications

- **Apply scientific reasoning** and/or **evidence** to **construct** an **explanation** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- Types of **evidence** may include, but are NOT limited to:
  - the age of materials (e.g., Earth rock, moon rock, meteorite) as determined by radiometric dating
  - number of impact craters on Earth compared to other planets
  - the size and/or composition of solar system objects (e.g., meteorites, moon)

- Examples of **changes during Earth's formation** and/or **early history** may include, but is NOT limited to:
  - bombardment of Earth and/or solar system objects
  - volcanic activity and/or the formation of continents and/or ocean basins

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>ESS2.A: Earth Materials and Systems
• Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.B: Plate Tectonics and Large-Scale System Interactions
• Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth’s surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth’s crust. (ESS2.B Grade 8 GBE)</td><td>Stability and Change
• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 56–59</td><td>pp. 179–182
pp. 182–183</td><td>pp. 98–101</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 6</td><td>Appendix E
p. 2</td><td>Appendix G
pp. 10–11</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment does not include memorization of the details of the formation of specific geographic features of Earth’s surface.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS2-1.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** based on **evidence** to illustrate how **Earth's internal** and/or **surface processes** operate at different **spatial** and/or **temporal scales** to form **continental** and/or **ocean-floor features**.
HS-ESS2-1.2	SEP-DCI	**Develop** and/or **use** a **model** based on **evidence** to illustrate a relationship between **Earth's internal** and/or **surface processes** and **continental** and/or **ocean-floor features**.
HS-ESS2-1.3	DCI-CCC	Connect **Earth's internal** and/or **surface processes** operating at different **spatial** and/or **temporal scales** to the formation of continental and/or **ocean-floor features**.
HS-ESS2-1.4	SEP-CCC	**Develop** and/or **use** a **model** based on **evidence** to illustrate changes at different **spatial** and/or **temporal scales** in a system.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or to describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- Types of **evidence** of **continental** and/or **ocean**-**floor features** may include, but are NOT limited to:
  - descriptions and/or locations of continental features (e.g., mountains)
  - descriptions and/or locations of ocean-floor features (e.g., deep ocean trenches)
  - geographic scale showing relative sizes/extents of continental and/or ocean-floor features
  - ages of continental and/or ocean-floor features

- **Evidence** of **Earth's internal** and/or **surface processes** may include, but is NOT limited to:
  - internal processes building up Earth's features (e.g., volcanism, tectonic uplift)
  - surface processes wearing away Earth's features (e.g., weathering, erosion)

- **Processes** operating at different **spatial** and/or **temporal scales** to form **features** may include, but are NOT limited to:
  - processes acting on long time scales to form or change features slowly (e.g., continental positions due to plate drift, tectonic plates pushing together to form mountains and/or deep ocean trenches, tectonic plates pulling apart to form new ocean floor, river wearing away rock to form a canyon)
  - processes acting on short time scales to form or change features rapidly (e.g., volcanic eruptions forming a lahar, earthquake causing a landslide)
  - processes acting on long or short time scales to cause irreversible changes to continental and/or ocean-floor features (e.g. subduction causing constant but slow destruction of ocean floor via subduction, rapid change of lava into igneous rocks, local uplift increasing the rate at which weathering affects surface rocks)

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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.</td><td>ESS2.A: Earth Materials and Systems
• Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.D: Weather and Climate
• The foundation for Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space.</td><td>Stability and Change
• Feedback (negative or positive) can stabilize or destabilize a system.

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
• New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 61–63</td><td>pp. 179–182
pp. 186–189</td><td>pp. 98–101</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 9</td><td>Appendix E
p. 2
Appendix E
p. 3</td><td>Appendix G
pp. 10–11
Appendix J
pp. 3–4</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth’s surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS2-2.1	SEP-DCI-CCC	**Analyze** geoscience **data** to make the claim that one **change** to Earth's surface can create **feedbacks** that affect the **stability** of other **Earth systems**.
HS-ESS2-2.2	SEP-DCI	**Analyze** geoscience **data** to make claims about relationships among Earth's surface and other **Earth systems**.
HS-ESS2-2.3	DCI-CCC	Connect **changes** to Earth's surface to **feedbacks** that affect the **stability** of other **Earth systems**.
HS-ESS2-2.4	SEP-CCC	**Analyze data** to make claims that feedback can affect the stability of systems.

Details and Clarifications

- **Analyze** geoscience **data** is expanded to include:
  - organizing and/or interpreting data using tables, graphs, and/or statistical analysis
  - identifying relationships in data using tables and/or graphs
  - identifying limitations (e.g., measurement error, sample selection) in data
  - comparing the consistency in measurements and/or observations in sets of data
  - using analyzed data to support a claim and/or an explanation

- **Earth systems** may include**:**
  - atmosphere
  - biosphere
  - cryosphere
  - geosphere
  - hydrosphere

- Examples of **changes** that can create **feedbacks** that affect **stability** may include, but are NOT limited to:
  - atmospheric and/or oceanic processes influencing land, organisms, weather, and/or climate
  - energy inputs from the sun interacting with matter in the atmosphere and/or Earth's surface to influence climate, organisms, and/or Earth's surface features
  - energy released from Earth's interior driving changes in Earth's surface features that influence weather, climate, living things, and/or oceans
  - water, ice, wind, and/or organisms interacting with materials on Earth's surface to shape landforms (i.e., through erosion, weathering, deposition)

<table>
<tr><th>Performance Expectation</th><th colspan="3">HS-ESS2-3 Develop a model based on evidence of Earth’s interior to describe the cycling of matter by thermal convection.</th></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence
• Science knowledge is based on empirical evidence.
• Science disciplines share common rules of evidence used to evaluate explanations about natural systems.
• Science includes the process of coordinating patterns of evidence with current theory.</td><td>ESS2.A: Earth Materials and Systems
• Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth’s surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth’s interior and gravitational movement of denser materials toward the interior.

ESS2.B: Plate Tectonics and Large-Scale System Interactions
• The radioactive decay of unstable isotopes continually generates new energy within Earth’s crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.</td><td>Energy and Matter
• Energy drives the cycling of matter within and between systems.

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
• Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 56–59</td><td>pp. 179–182
pp. 182–183</td><td>pp. 94–96
pp. 210–214</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 6
Appendix H
p. 5</td><td>Appendix E
p. 2</td><td>Appendix G
pp. 8–9
Appendix J
p. 3</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth’s three-dimensional structure obtained from seismic waves, records of the rate of change of Earth’s magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth’s layers from high-pressure laboratory experiments.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS2-3.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** based on **evidence** of **Earth's interior** to describe the **cycling** of **matter** by **thermal convection.**
HS-ESS2-3.2	SEP-DCI	**Develop** and/or **use** a **model** based on **evidence** to describe **matter** and/or **thermal convection** in **Earth's interior.**
HS-ESS2-3.3	DCI-CCC	Connect **evidence** of **Earth's interior** to the **cycling** of **matter** by **thermal convection.**
HS-ESS2-3.4	SEP-CCC	**Develop** and/or **use** a **model** based on evidence to describe how energy drives the cycling of matter in a system.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or to describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- **Models** may include, but are NOT limited to, diagrams, tables, graphs, and/or simulations showing:
  - Earth's radial layers (e.g., crust, mantle, liquid outer core, solid inner core) determined by density
  - heat loss at Earth's surface
  - patterns of geothermal gradients
  - convection currents

- Types of **evidence** of **Earth's interior** may include, but are NOT limited to:
  - records of historical changes in Earth's surface and magnetic field
  - composition of samples taken from deep probes
  - behavior of seismic waves
  - heat flow measurements

- Describing the **cycling of matter** by **thermal convection** may include, but is NOT limited to:
  - radioactive decay and thermal energy contributing to the flow of matter in the mantle
  - convection causing hot matter to rise and cool matter to sink
  - thermal energy driving convection due to changes in density
  - thermal energy being released at Earth's surface as new crust cools and forms
  - flow of matter by convection in the liquid outer core generating the Earth's magnetic field
  - crust material sinking into mantle material at subduction zones

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
• Use a model to provide mechanistic accounts of phenomena.

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence
• Science arguments are strengthened by multiple lines of evidence supporting a single explanation.</td><td>ESS1.B: Earth and the Solar System
• Cyclical changes in the shape of Earth’s orbit around the sun, together with changes in the tilt of the planet’s axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary)

ESS2.A: Earth Materials and System
• The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun’s energy output or Earth’s orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

ESS2.D: Weather and Climate
• The foundation for Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 56–59</td><td>pp. 175–176
pp. 179–182
pp. 186–189</td><td>pp. 87–89</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 6
Appendix H
p. 5</td><td>Appendix E
p. 3</td><td>Appendix G
pp. 5–6</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS2-4.1	SEP-DCI-CCC	**Develop** and/or **use** a **model** to describe **cause and effect** relationships between variations in the **flow** of **energy** into and/or out of Earth systems and **changes** in **climate**.
HS-ESS2-4.2	SEP-DCI	**Develop** and/or **use** a **model** to describe variations in the **flow** of **energy** into and/or out of Earth systems and/or to describe **changes** in **climate**.
HS-ESS2-4.3	DCI-CCC	Use **cause and effect** relationships to connect variations in the **flow** of **energy** into and/or out of Earth systems to **changes** in **climate**.
HS-ESS2-4.4	SEP-CCC	**Develop** and/or **use** a **model** to describe cause and effect relationships in a system.

Details and Clarifications

- **Develop** and/or **use** a **model** is expanded to include:
  - developing, revising, and/or using a model to generate data
  - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
  - using a given complete or partial model to make predictions and/or to describe phenomena
  - revising a given complete or partial model
  - describing the limitations of a complete or partial model
  - comparing models of a given system

- **Models** may include, but are NOT limited to, a diagram, simulation, or written description of:
  - factors that affect input, output, storage, and/or redistribution of energy
  - factors that operate over a variety of timescales

- Factors that affect the **flow** of **energy** may include, but are NOT limited to:
  - Earth's orbit and/or orientations of Earth's axis
  - the sun's energy output
  - configuration of continents resulting from tectonic activity
  - volcanic activity
  - ocean circulation
  - atmospheric composition and/or circulation
  - vegetation cover
  - human activities

- Evidence of **changes** in **climate** may include, but is NOT limited to:
  - significant changes in average global temperature
  - significant rises in sea levels or changes in ocean temperature
  - significant changes in weather patterns

- **Cause and effect** relationships may include, but are NOT limited to:
  - the burning of fossil fuels increases CO_2 in the atmosphere, which traps thermal energy and results in increased global surface temperatures
  - volcanic eruptions release particles into the atmosphere that shade incoming solar radiation, resulting in cooling that can last from months to years
  - ocean currents transport warm water from the equator toward the poles and cold water from the poles toward the equator, regulating global climate and counteracting the uneven distribution of solar radiation reaching Earth's surface

<table>
<tr><th>Performance Expectation</th><th colspan="3">HS-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.</th></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Planning and Carrying Out Investigations
Planning and carrying out investigations in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.
• 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.</td><td>ESS2.C: The Roles of Water in Earth's Surface Processes
• The abundance of liquid water on Earth’s surface and its unique combination of physical and chemical properties are central to the planet’s dynamics. These properties include water’s exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.</td><td>Structure and Function
• The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 59–61</td><td>pp. 184–186</td><td>pp. 96–98</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 7–8</td><td>Appendix E
p. 3</td><td>Appendix G
pp. 9–10</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS2-5.1	SEP-DCI-CCC	**Plan** and/or **conduct** an **investigation** of the **properties** of **water** and its **effects** on **Earth materials** and/or **surface processes**.
HS-ESS2-5.2	SEP-DCI	**Plan** and/or **conduct** an **investigation** of **water's effects** on **Earth materials** and/or **surface processes**.
HS-ESS2-5.3	DCI-CCC	Connect **the properties** of **water** to its **effects** on **Earth materials** and/or **surface processes**.
HS-ESS2-5.4	SEP-CCC	**Plan** and/or **conduct** an **investigation** of structure and function relationships in a system.

Details and Clarifications

- **Plan** and/or **conduct** an **investigation** is expanded to include:
  - planning for and/or producing data to serve as evidence for developing and/or revising models, supporting an explanation, and/or testing a solution
  - planning for and/or evaluating an investigation to identify possible confounding variables and/or to ensure that variables are controlled
  - determining the type, amount, and/or accuracy of data needed to produce reliable measurements and/or considering limitations on the precision of the data (e.g., number of trials, cost, risk, time)
  - selecting appropriate processes, methods, and/or tools to collect, record, analyze, and/or evaluate data
  - predicting what happens to a dependent variable when an independent variable is manipulated
  - identifying failure points and/or describing performance relative to criteria for success

- **Properties** of **water** may include, but are NOT limited to:
  - heat capacity
  - density
  - polarity
  - ability to flow
  - ability to dissolve materials

- **Effects of water's properties** on **Earth materials** and/or **surface processes** may include, but are NOT limited to:
  - water transferring energy causing changes in temperature, air movement, water movement, and/or water availability
  - water transporting and/or depositing materials
  - water preventing the movement of materials
  - water breaking rock apart as water freezes
  - water dissolving and/or recrystallizing materials
  - water decreasing the viscosity of melted rock

Performance Expectation	**HS-ESS2-6** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**ESS2.D: Weather and Climate** • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. • Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.	**Energy and Matter** • The total amount of energy and matter in closed systems is conserved.
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 56–59	pp. 186–189	pp. 94–96
NGSS Appendices	Appendix F p. 6	Appendix E p. 3	Appendix G pp. 8–9
Clarification Statement	Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.		
Assessment Boundary	An assessment boundary is not provided for this PE.		

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS2-6.1	SEP-DCI-CCC	**Develop** and/or **use** a **quantitative model** to describe how **matter** is **conserved** as **carbon cycles** among the hydrosphere, atmosphere, geosphere, and/or biosphere.
HS-ESS2-6.2	SEP-DCI	**Develop** and/or use a **quantitative model** to describe how **carbon cycles** among the hydrosphere, atmosphere, geosphere, and/or biosphere.
HS-ESS2-6.3	DCI-CCC	Connect the **conservation of matter** and the **cycling** of **carbon** among the hydrosphere, atmosphere, geosphere, and/or biosphere.
HS-ESS2-6.4	SEP-CCC	**Develop** and/or use a **quantitative model** to describe how matter is conserved in a system.

Details and Clarifications

- **Develop** and/or **use** a **quantitative model** is expanded to include:
    - developing, revising, and/or using a model to generate data
    - developing, revising, and/or using a model to show relationships between the components of a system and/or between systems
    - using a given complete or partial model to make predictions and/or to describe phenomena
    - revising a given complete or partial model
    - describing the limitations of a complete or partial model
    - comparing models of a given system

- Examples of how **matter** is **conserved** as **carbon cycles** may include, but are NOT limited to:
    - relative concentrations and/or quantities of carbon stored in Earth systems and/or reservoirs
    - rates of carbon transfer among Earth systems and/or reservoirs
    - the effects of natural processes and/or human activities on the concentration of CO_2 in the atmosphere and/or the subsequent effects on climate
    - measurements and/or calculations of carbon storage and/or carbon cycling among Earth systems and/or reservoirs
    - gradual movement of carbon between the biosphere and the atmosphere during photosynthesis and/or cellular respiration

Performance Expectation	**HS-ESS2-7** Construct an argument based on evidence about the simultaneous coevolution of Earth’s systems and life on Earth.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Construct an oral and written argument or counter-arguments based on data and evidence.	**ESS2.D: Weather and Climate** • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. **ESS2.E Biogeology** • The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth’s surface and the life that exists on it.	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 71–74	pp. 186–189 pp. 189–190	pp. 98–101
NGSS Appendices	Appendix F pp. 13–14	Appendix E p. 3	Appendix G pp. 10–11
Clarification Statement	Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth’s other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth’s surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.		
Assessment Boundary	Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth’s other systems.		

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS2-7.1	SEP-DCI-CCC	**Construct** an **argument** based on **evidence** about the simultaneous **coevolution** of **Earth's systems** and **life on Earth**.
HS-ESS2-7.2	SEP-DCI	**Construct** an **argument** based on **evidence** about **Earth's systems** and **life on Earth**.
HS-ESS2-7.3	DCI-CCC	Connect **coevolution** to changes in **Earth's systems** and **life on Earth**.
HS-ESS2-7.4	SEP-CCC	**Construct** an **argument** based on **evidence** of change and/or stability in a system.

Details and Clarifications

- **Construct** and/or use an **argument** is expanded to include:
  - describing criteria used to critique claims
  - using evidence to compare and/or evaluate competing arguments and/or solutions
  - using evidence to determine the merit of an argument and/or an explanation
  - using evidence to construct and/or support an argument and/or a claim
  - evaluating competing design solutions to real-world problems using scientific ideas and/or evidence and/or relevant economic, societal, and/or environmental considerations

- **Earth's systems** may include, but are NOT limited to:
  - atmosphere
  - biosphere
  - geosphere
  - hydrosphere
  - cryosphere

- **Evidence** of changes in **Earth's systems** may include, but is NOT limited to:
  - greenhouse gas concentrations increasing over time
  - weathering rates increasing over time
  - patterns of erosion and/or deposition changing along coastlines over time
  - pH of ocean water decreasing over time
  - differences and/or similarities in rocks and/or soils appearing in rock strata

- **Evidence** of changes in **life on Earth** may include, but is NOT limited to:
  - fossils documenting the existence of now-extinct past species that are related to present-day species
  - species sharing similar physical features because the feature was present in a common ancestor
  - DNA and/or the genetic code reflecting shared ancestry

- **Evidence** of **coevolution** may include, but is NOT limited to:
  - plant processes and/or human activities affecting atmospheric gas concentrations
  - presence or absence of plant and/or animal life changing rates of weathering
  - microbial activity increasing the formation of soils and/or evolution of plants
  - changes in organisms influencing the circulation and/or chemical properties of ocean water
  - global distribution of organisms and/or the unique features of island species reflecting evolution and geological change

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories. • Construct 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.	**ESS3.A: Natural Resources** • Resource availability has guided the development of human society. **ESS3.B: Natural Hazards** • Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **Connections to Engineering, Technology, and Applications of Science** **Influence of Science, Engineering, and Technology on Society and the Natural World** • Modern civilization depends on major technological systems.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 67–71	pp. 191–192 pp. 192–194	pp. 87–89 pp. 210–214
NGSS Appendices	Appendix F pp. 11–12	Appendix E p. 3	Appendix G pp. 5–6 Appendix J pp. 3–4
Clarification Statement	Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.		
Assessment Boundary	An assessment boundary is not provided for this PE.		

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS3-1.1	SEP-DCI-CCC	**Construct** an **explanation** based on evidence for how the availability of **natural resources**, occurrence of **natural hazards**, and/or **changes in climate** have **influenced human activity**.
HS-ESS3-1.2	SEP-DCI	**Construct** an **explanation** based on evidence for the availability of **natural resources**, occurrence of **natural hazards**, and/or **changes in climate**.
HS-ESS3-1.3	DCI-CCC	Connect the availability of **natural resources**, occurrence of **natural hazards**, and/or **changes in climate** to their **influences** on **human activity**.
HS-ESS3-1.4	SEP-CCC	**Construct** an **explanation** based on evidence about cause and effect relationships.

Details and Clarifications

- **Construct** an **explanation** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- Examples of **natural resources** may include, but are NOT limited to:
  - soil
  - water (e.g., rivers, lakes, oceans, groundwater)
  - metallic minerals (e.g., iron, copper)
  - non-metallic minerals (e.g., phosphorus, salt)
  - fossil fuels (e.g., oil, coal, natural gas)
  - vegetation (e.g., forests)

- Examples of **natural hazards** may include, but are NOT limited to:
  - geophysical (e.g., volcanic eruptions, earthquakes, tsunamis, landslides)
  - hydrological (e.g., avalanches, floods)
  - climatological (e.g., droughts, wildfires, extreme temperatures)
  - meteorological (e.g., storms)
  - biological (e.g., disease)

- Indications of **changes in climate** may include, but are NOT limited to:
  - changes in sea level, amount of precipitation, and/or temperature
  - increases in the frequency and/or severity of hazardous weather events
  - the spreading of diseases (e.g., malaria) to new locations
  - the melting of glaciers

- Examples of **influences** on **human activity** may include, but are NOT limited to:
  - changes in types of agriculture (e.g., crops, livestock) to match a shifting climate
  - increases in monitoring activities to forecast the course of volcanic eruptions
  - decreases in human populations in areas that have become prone to flooding
  - relocation of human populations to areas with locations with natural gas stores
  - development of new technologies to mitigate the effects of natural hazards

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
• Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).</td><td>ESS3.A: Natural Resources
• All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

ETS1.B: Developing Possible Solutions
• When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary)</td><td>Connections to Engineering, Technology, and Applications of Science
Influence of Science, Engineering, and Technology on Society and the Natural World
• Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
• Analysis of costs and benefits is a critical aspect of decisions about technology.
Connections to Nature of Science
Science Addresses Questions About the Natural and Material World
• Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.
• Science knowledge indicates what can happen in natural systems — not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.
• Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 71–74</td><td>pp. 191–192
pp. 206–208</td><td></td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 13–14</td><td>Appendix E
p. 3
Appendix I
pp. 1–7</td><td>Appendix J
pp. 3–4
Appendix H
p. 6</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS3-2.1	SEP-DCI-CCC	**Evaluate** competing **design solutions** for developing, managing, and/or utilizing **energy** and/or **mineral resources** based on **costs, benefits,** and/or **societal needs** and/or **wants**.
HS-ESS3-2.2	SEP-DCI	**Evaluate** competing **design solutions** for developing, managing, and/or utilizing **energy** and/or **mineral resources**.
HS-ESS3-2.3	DCI-CCC	Connect **costs, benefits,** and/or **societal needs** and/or **wants** to utilizing **energy** and/or **mineral resources.**
HS-ESS3-2.4	SEP-CCC	**Evaluate** competing **design solutions** based on costs, benefits, and/or societal needs and/or wants.

Details and Clarifications

- **Evaluate** competing **design solutions** is expanded to include**:**
  - describing criteria used to critique claims
  - using evidence to compare and/or evaluate competing arguments and/or solutions
  - using evidence to determine the merit of an argument and/or an explanation
  - using evidence to construct and/or support an argument and/or a claim
  - evaluating competing design solutions to real world problems using scientific ideas and/or evidence and/or relevant economic, societal, and/or environmental considerations

- Examples of **design solutions** related to **energy** and/or **mineral resources** may include, but are NOT limited to, technologies and/or methods for:
  - enhancing renewable energy as a source of energy production
  - improving technologies associated with the extraction of metal, mineral, and/or fossil fuel resources
  - increasing the availability of natural resources through conservation, recycling, and/or reuse
  - determining locations where resource extraction is viable and/or impact is minimal

- Examples of **costs, benefits** and/or **societal needs** and/or **wants** may include, but are NOT limited to:
  - economic (e.g., cost of extracting resources and/or developing energy, value of resources)
  - social (e.g., resource locations correlated to size of human populations, societal needs for resources)
  - environmental (e.g., earthquakes after extracting resources, displacement of organisms, habitat destruction)
  - geopolitical (e.g., international trade of resources, collaborative design solutions)

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS3-3 Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Using Mathematics and Computational Thinking
Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
• Create a computational model or simulation of a phenomenon, designed device, process, or system.</td><td>ESS3.C: Human Impacts on Earth Systems
• The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.</td><td>Stability and Change
• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World
• Modern civilization depends on major technological systems.
• New technologies can have deep impacts on society and the environment, including some that were not anticipated.

Connections to Nature of Science

Science is a Human Endeavor
• Science is a result of human endeavors, imagination, and creativity.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 64–67</td><td>pp. 194–196</td><td>pp. 98–101
pp. 210–214</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 10</td><td>Appendix E
p. 3</td><td>Appendix G
pp. 10–11
Appendix J
pp. 3–4
Appendix H
p. 6</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS3-3.1	SEP-DCI-CCC	**Create** and/or **use** a computational **simulation** to illustrate the **stability** and **change** relationships among the **management** of **natural resources**, the **sustainability** of **human populations**, and/or **biodiversity**.
HS-ESS3-3.2	SEP-DCI	**Create** and/or **use** a computational **simulation** to illustrate the **management** of **natural resources**, the **sustainability** of **human populations**, and/or **biodiversity**.
HS-ESS3-3.3	DCI-CCC	**Connect stability** and **change** relationships to the **management** of **natural resources**, the **sustainability** of **human populations**, and/or **biodiversity**.
HS-ESS3-3.4	SEP-CCC	**Create** and/or **use** a computational **simulation** to illustrate stability and change in relationships within a system or between systems.

Details and Clarifications

- **Create** and/or **use** a computational **simulation** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
  - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems

- **Simulations** may include, but are NOT limited to:
  - mathematical relationships between components of a system
  - variables to illustrate relationships among system components
  - formulas that model mathematical relationships of the sustainability of human societies

- Factors affecting the responsible **management** of **natural resources**, the **sustainability** of **human populations,** and/or **biodiversity** may include, but are NOT limited to:
  - reusing and/or recycling materials
  - regulating pollution, recreation, and/or development
  - developing alternative energy sources
  - developing technology that produces less pollution and/or waste

- **Stability** and **change** relationships may include, but are NOT limited to**:**
  - how altering one component in a system affects other components
  - how the use of a technology affects the stability, change, and/or rates of change in a system
  - how interactions among components of a system result in the stabilization or destabilization of the system

<table>
<tr><th>Performance Expectation</th><th colspan="3">HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.</th></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles and theories.
• Design or refine a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.</td><td>ESS3.C: Human Impacts on Earth Systems
• Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

ETS1.B: Developing Possible Solutions
• When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary)</td><td>Stability and Change
• Feedback (negative or positive) can stabilize or destabilize a system.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World
• Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K–12 Framework</td><td>pp. 67–71</td><td>pp. 194–196
pp. 206–208</td><td>pp. 98–101
pp. 210–214</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
pp. 11–12</td><td>Appendix E
p. 3
Appendix I
pp. 1–7</td><td>Appendix G
pp. 10–11
Appendix J
pp. 3–4</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">An assessment boundary is not provided for this PE.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS3-4.1	SEP-DCI-CCC	**Evaluate** and/or **refine** a **technological solution** that **reduces impacts** of **human activities** on natural systems.
HS-ESS3-4.2	SEP-DCI	**Evaluate** and/or **refine** a **technological solution** to problems caused by **impacts** of **human activities** on natural systems.
HS-ESS3-4.3	DCI-CCC	Connect **reducing impacts** of **human activities** to changes in natural systems.
HS-ESS3-4.4	SEP-CCC	**Evaluate** and/or **refine** a **technological solution** that reduces impacts on a system.

Details and Clarifications

- **Evaluate** and/or **refine** a **technological solution** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- **Technological solutions** that **reduce impacts** may include, but are NOT limited to:
  - reducing, reusing, and/or recycling resources
  - treating waste materials (e.g., sewage)
  - developing alternative energy sources
  - developing technologies that reduce pollution

- **Impacts** of **human activities** may include, but are NOT limited to:
  - soil movement harming water supply and/or water ecosystems
  - air and/or water pollution damaging species and/or natural habitats
  - pollution and/or waste harming agriculture and/or decreasing biodiversity

<table>
<tr><td>Performance Expectation</td><td colspan="3">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's systems.</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Science & Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
• Analyze data using computational models in order to make valid and reliable scientific claims.

Connections to Nature of Science

Scientific Investigations Use a Variety of Methods
• Science investigations use diverse methods and do not always use the same set of procedures to obtain data.
• New technologies advance scientific knowledge.

Scientific Knowledge is Based on Empirical Evidence
• Science knowledge is based on empirical evidence.
• Science arguments are strengthened by multiple lines of evidence supporting a single explanation</td><td>ESS3.D: Global Climate Change
• Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.</td><td>Stability and Change
• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</td></tr>
<tr><td colspan="4">These item specifications were developed using the following reference materials:</td></tr>
<tr><td>K-12 Framework</td><td>pp. 61–63</td><td>pp. 196–198</td><td>pp. 98–101</td></tr>
<tr><td>NGSS Appendices</td><td>Appendix F
p. 9
Appendix H
p. 5</td><td>Appendix E
p. 4</td><td>Appendix G
pp. 10–11</td></tr>
<tr><td>Clarification Statement</td><td colspan="3">Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition)</td></tr>
<tr><td>Assessment Boundary</td><td colspan="3">Assessment is limited to one example of a climate change and its associated impacts.</td></tr>
</table>

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS3-5.1	SEP-DCI-CCC	**Analyze** geoscience **data** and/or the results from global climate **models** to make an evidence-based forecast of the current rate of global and/or regional **climate change** and/or associated future **impacts** to **Earth's systems**.
HS-ESS3-5.2	SEP-DCI	**Analyze** geoscience **data** and/or the results from global climate **models** to describe global and/or regional **climates** and/or **Earth's systems**.
HS-ESS3-5.3	DCI-CCC	Connect evidence of the current rate of global or regional **climate change** to associated future **impacts** to **Earth's systems**.
HS-ESS3-5.4	SEP-CCC	**Analyze data** to describe changes to a system.

Details and Clarifications

- **Analyze data** is expanded to include:
  - organizing and/or interpreting data using tables, graphs, and/or statistical analysis
  - identifying relationships in data using tables and/or graphs
  - identifying limitations (e.g., measurement error, sample selection) in data
  - comparing the consistency in measurements and/or observations in sets of data
  - using analyzed data to support a claim and/or an explanation

- **Data** may include, but are NOT limited to:
  - temperature
  - precipitation
  - sea level
  - glacial and/or sea ice volume
  - atmosphere, geosphere, or hydrosphere composition

- **Models** may include, but are NOT limited to:
  - simulations
  - mathematical equations
  - graphical displays of data (e.g., map, chart, table, graph)

- Examples of **climate change** may include, but are NOT limited to:
  - change in a physical parameter (e.g., CO_2 concentration, temperature, precipitation) of Earth’s atmosphere over time
  - change in a chemical characteristic (e.g., pH) of Earth’s oceans over time

- Examples of **impacts** to **Earth’s systems** may include, but are NOT limited to:
  - an increase in average global temperatures
  - an increase in average sea level
  - an increase in extreme weather events (e.g., hurricanes, flooding)
  - a decrease in arctic sea ice
  - reversible and/or irreversible changes

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Using Mathematics and Computational Thinking Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.	**ESS2.D: Weather and Climate** • Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. *(secondary)* **ESS3.D: Global Climate Change** • Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.	**Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 64–67	pp. 186–189 pp. 196–198	pp. 91–94
NGSS Appendices	Appendix F p. 10	Appendix E p. 3 Appendix E p. 4	Appendix G pp. 7–8
Clarification Statement	Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.		
Assessment Boundary	Assessment does not include running computational representations but is limited to using the published results of scientific computational models.		

Items may ask students to:

Code	Alignment	Item Specification
HS-ESS3-6.1	SEP-DCI-CCC	**Use** a **computational representation** to illustrate the **relationships** among **Earth systems** and how those **relationships** are being **modified** due to **human activity**.
HS-ESS3-6.2	SEP-DCI	**Use** a **computational representation** to illustrate how Earth is being **modified** due to **human activity**.
HS-ESS3-6.3	DCI-CCC	Connect **relationships** among **Earth systems** to how those **relationships** are being **modified** due to **human activity**.
HS-ESS3-6.4	SEP-CCC	**Use** a **computational representation** to illustrate interactions within a system and/or among systems.

Details and Clarifications

- **Use** a **computational representation** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
  - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems

- **Earth systems** may include:
  - hydrosphere
  - atmosphere
  - cryosphere
  - geosphere
  - biosphere

- Examples of **human activities** that **modify relationships** among **Earth systems** may include, but are NOT limited to:
  - construction (e.g., roads, buildings) leading to an increase in erosion and a loss of habitat
  - fossil fuel combustion releasing greenhouse gases, leading to an increase in Earth's average surface temperature and a loss of sea ice

Engineering, Technology, and Applications of Science

Disciplinary Core Ideas:

- ETS1 Engineering Design

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Asking Questions and Defining Problems Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Analyze complex real-world problems by specifying criteria and constraints for successful solutions.	**ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.	**Connections to Engineering, Technology, and Applications of Science** **Influence of Engineering, Technology, and Science on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 54–56	pp. 204–206	pp. 210–214
NGSS Appendices	Appendix F pp. 4–5	Appendix I pp. 1–7	Appendix J pp. 3–4
Clarification Statement	A clarification statement is not provided for this PE.		
Assessment Boundary	An assessment boundary is not provided for this PE.		

Items may ask students to:

Code	Alignment	Item Specification
HS-ETS1-1.1	SEP-DCI-CCC	**Analyze** a major **global challenge** to specify **qualitative** and/or **quantitative criteria** and/or **constraints** for solutions that account for **societal needs** and/or **wants**.
HS-ETS1-1.2	SEP-DCI	**Analyze** a major **global challenge** to specify **qualitative** and/or **quantitative criteria** and/or **constraints**.
HS-ETS1-1.3	DCI-CCC	Describe **qualitative** and/or **quantitative criteria** and/or **constraints** for solutions that account for **societal needs** and/or **wants**.
HS-ETS1-1.4	SEP-CCC	**Analyze** a major **global challenge** to solutions that account for **societal needs** and/or **wants**.

Details and Clarifications

- **Analyze** a **global challenge** is expanded to include:
  - asking and/or identifying questions that arise from observation and/or investigation to seek additional information
  - asking questions to determine quantitative and/or qualitative relationships, between independent and dependent variables
  - asking questions to refine a model, an explanation, and/or an engineering problem
  - asking questions to determine if a question is testable and/or relevant
  - asking questions that frame a hypothesis based on observations and/or scientific principles
  - asking questions that challenge an argument, data set, and/or design
  - defining a design problem that involves the development of a process and/or system with interacting components
  - describing social, technical, and/or environmental criteria for a successful solution
  - describing social, technical, and/or environmental constraints that could limit the success of a solution

- Examples of **global challenges** that account for a **societal need** and/or **want** may include, but are NOT limited to:
  - managing urbanization and/or water management to provide access to clean drinking water
  - improving soil quality and/or seed quality to provide access to food
  - providing access to renewable and/or affordable energy without harming the environment
  - managing greenhouse gas emissions to reduce the impacts of global climate change

- Examples of **criteria** for a successful solution may include, but are NOT limited to, **qualitative** and/or **quantitative** descriptions of:
  - desired cost
  - desired functionality and/or performance
  - desired health and/or environmental effects

- Examples of **constraints** that limit the success of a solution may include, but are NOT limited to, **qualitative** and/or **quantitative** descriptions of:
  - high cost
  - issues in functionality and/or performance
  - health and/or environmental risks

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. • Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.	
These item specifications were developed using the following reference materials:			
K-12 Framework	pp. 67–71	pp. 208–210	
NGSS Appendices	Appendix F pp. 11–12	Appendix I pp. 1–7	
Clarification Statement	A clarification statement is not provided for this PE.		
Assessment Boundary	An assessment boundary is not provided for this PE.		

Items may ask students to:

Code	Alignment	Item Specification
HS-ETS1-2.1	SEP-DCI-CCC	Due to the lack of a CCC, items are not coded HS-ETS1-2.1.
HS-ETS1-2.2	SEP-DCI	**Design** a **solution** to a complex real-world problem by breaking the problem down into smaller, more manageable problems that can be **evaluated systematically** using **prioritized criteria** and/or **tradeoff considerations**.
HS-ETS1-2.3	DCI-CCC	Due to the lack of a CCC, items are not coded HS-ETS1-2.3.
HS-ETS1-2.4	SEP-CCC	Due to the lack of a CCC, items are not coded HS-ETS1-2.4.

Details and Clarifications

- **Design** a **solution** is expanded to include:
    - making claims about relationships between dependent and independent variables
    - using valid and/or reliable evidence to construct and/or revise an explanation
    - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
    - using evidence to evaluate how well a solution meets the criteria for success
    - using evidence to evaluate the constraints that may limit the success of a solution
    - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- **Prioritized criteria** may include, but are NOT limited to:
    - relatively low impact on the environment and/or the health of organisms
    - relatively high effectiveness in solving specific aspects of the given problem
    - relatively high reliability
    - relative availability of technology
    - relative use of materials with desired and/or required properties

- **Tradeoff considerations** may include, but are NOT limited to:
    - describing advantages and/or disadvantages of a solution
    - comparing the benefits of several solutions

- **Evaluated systematically** may include, but is NOT limited to:
    - comparing the tradeoffs for several solutions
    - using a numerical weighting system to prioritize criteria
    - evaluating and/or comparing a top criterion (e.g., safety) with impacts on other criteria (e.g., cost)
    - describing the interconnectedness of criteria, solutions, and/or tradeoffs for the sub-problems of a complex problem

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. • Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.	**Connections to Engineering, Technology, and Applications of Science** **Influence of Engineering, Technology, and Science on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 67–71	pp. 206–208	pp. 210–214
NGSS Appendices	Appendix F pp. 11–12	Appendix I pp. 1–7	Appendix J pp. 3–4
Clarification Statement	A clarification statement is not provided for this PE.		
Assessment Boundary	An assessment boundary is not provided for this PE.		

Items may ask students to:

Code	Alignment	Item Specification
HS-ETS1-3.1	SEP-DCI-CCC	**Evaluate** a **solution** to a complex real-world **problem** based on prioritized **criteria** and/or **trade-offs** that account for a range of **constraints** and/or **impacts**.
HS-ETS1-3.2	SEP-DCI	**Evaluate** a **solution** to a complex real-world **problem** based on prioritized **criteria** and/or **trade-offs** that account for a range of **constraints**.
HS-ETS1-3.3	DCI-CCC	Use prioritized **criteria** and/or **trade-offs** to account for a range of **constraints** on and/or **impacts** of the **solution** to a complex real-world **problem**.
HS-ETS1-3.4	SEP-CCC	**Evaluate** a **solution** to account for a range of impacts.

Details and Clarifications

- **Evaluate** a **solution** is expanded to include:
  - making claims about relationships between dependent and independent variables
  - using valid and/or reliable evidence to construct and/or revise an explanation
  - applying scientific ideas, principles, and/or evidence to describe a scientific phenomenon and/or solve a problem
  - using evidence to evaluate how well a solution meets the criteria for success
  - using evidence to evaluate the constraints that may limit the success of a solution
  - using knowledge, evidence, criteria, and/or tradeoffs to evaluate and/or refine a solution

- Examples of complex real-world **problems** may include, but are NOT limited to:
  - air pollution
  - global climate change
  - depletion of natural resources

- Examples of **criteria** for a successful solution may include, but are NOT limited to:
  - relatively low impact on the environment and/or the health of organisms
  - relative availability of technology
  - relatively high effectiveness in solving specific aspects of the given problem
  - relative use of materials with desired and/or required properties

- **Trade-offs** may include, but are NOT limited to:
  - advantages and/or disadvantages for a solution

- Examples of **constraints** that limit the success of a solution may include, but are NOT limited to:
  - relatively high risks to health and/or the environment
  - relatively high cost
  - relatively low availability of technology
  - relatively low reliability
  - issues in functionality and/or performance
  - use of materials with undesirable properties

- Examples of **impacts** of a solution may include, but are NOT limited to:
  - reduction of resources available to solve other problems
  - social or cultural influences
  - risks to health and/or safety
  - environmental changes

Performance Expectation	**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.		
Dimensions	**Science & Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
	Using Mathematics and Computational Thinking Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems.	**ETS1.B: Developing Possible Solutions** • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.
These item specifications were developed using the following reference materials:			
K–12 Framework	pp. 64–67	pp. 206–208	pp. 91–94
NGSS Appendices	Appendix F p. 10	Appendix I pp. 1–7	Appendix G pp. 7–8
Clarification Statement	A clarification statement is not provided for this PE.		
Assessment Boundary	An assessment boundary is not provided for this PE.		

Items may ask students to:

Code	Alignment	Item Specification
HS-ETS1-4.1	SEP-DCI-CCC	**Use** a **computer simulation** to **model** the **impact** of proposed solutions to a **complex real-world problem** with numerous criteria and/or constraints on interactions within and/or between **systems.**
HS-ETS1-4.2	SEP-DCI	**Use** a **computer simulation** to **model** the **impact** of proposed solutions to a **complex real-world problem** with numerous criteria and/or constraints.
HS-ETS1-4.3	DCI-CCC	Connect solutions to a **complex real-world problem** to the **impact** of the proposed solutions with numerous criteria and/or constraints on interactions within and/or between **systems**.
HS-ETS1-4.4	SEP-CCC	**Use** a **computer simulation** to model interactions within and/or among systems.

Details and Clarifications

- **Use** a **computer simulation** is expanded to include:
  - describing and/or revising a computational model or simulation of a phenomenon, designed device, process, and/or system
  - using mathematical, computational, and/or algorithmic representations of phenomena and/or design solutions to describe and/or support claims and/or explanations
  - applying techniques of algebra and/or functions to represent and/or solve scientific and/or engineering problems

- Components of a **computer simulation** that **models** interactions within and/or between **systems** may include, but are NOT limited to:
  - a defined problem
  - solutions to a problem
  - variables being used to test/evaluate proposed solutions
  - criteria for success of solutions to a problem (e.g., have a positive effect on a high number of people, high efficiency, low safety risks)
  - constraints on the success of solutions to a problem (e.g., too little space, too high cost, uses rare materials, environment is negatively impacted)
  - boundaries of systems

- Examples of **modeling** the **impact** of proposed solutions may include, but are NOT limited to:
  - selecting inputs
  - simulating the effects of solutions and/or processes
  - simulating the effects of changing variables on the outcomes
  - interpreting the results of a simulation
  - comparing simulation results to expected results
  - describing negative consequences and/or trade-offs

- Examples of **complex real-world problems** may include, but are NOT limited to:
  - climate change
  - food insecurity
  - clean water
  - energy sources

SEP, DCI, and CCC Vocabulary Used in Assessment Items at Grade 11

Items use language targeted to the previous grade level or lower readability with the exception of the required SEP, DCI, and CCC terms in the following list. Appropriate science vocabulary allowed for the grades 5 and 8 WCAS may also be used for the grade 11 WCAS. Vocabulary words from the earlier grade levels are included in the list.

a

Used in grade 5:
absorb
acid
advantage
amplitude
angle
apparent brightness
attract
axis

Used in grade 8:
acceleration
adaptation
algae
allele
analog signal
artificial selection
asexual reproduction
atom

Used in grade 11:
aerobic
alpha decay
amino acid
anaerobic
aqueous

b

Used in grade 5:
balanced force
behavior
biosphere

Used in grade 8:
biodiversity
boiling point

Used in grade 11:
beta decay
biomass
bond energy

c

Used in grade 5:
camouflage
cause
characteristic
charge
claim
classify
climate
collision
communicate
compare
conclusion
condense
conductivity
conserve
constraint
continent
criteria

Used in grade 8:
cell membrane
cell wall
cellular respiration
chemical change
chemical property
chemical reaction
chloroplasts
chromosome
components
concentration (of a solution)
consumer
continental crust
correlation
crystallization

Used in grade 11:
carrying capacity
chemical bond
chemical energy
coevolution
combustion
compound
conduction
convection
cosmic microwave background radiation
cryosphere

d

Used in grade 5:
data
decomposer
decrease
deep ocean trench
defend
demonstration
describe
design
development
device
diagram
digital signal
disadvantage
disease
distance

Used in grade 8:
density
durability

Used in grade 11:
degradation
differentiate
diffraction
DNA
DNA replication

e

Used in grade 5:
earthquake
ecosystem
effect
electric current
electric force
electrical energy
electricity
electromagnet
energy
engineer
environment
erosion

eruption
evaporate
evidence
exert
extinct

Used in grade 8:
eclipse
electric circuit
electric field
element
embryo
emit
evolution

Used in grade 11:
electromagnetic radiation
electron
electronegativity
elliptical orbit
energy conversion
equilibrium

f
Used in grade 5:
factor
fault
food web
fossil
fossil fuel
function
fungi

Used in grade 8:
field energy
flammable
fossil record
frequency

g
Used in grade 5:
gas
geosphere
glacier
global
graph
gravitational force
gravity
groundwater

Used in grade 8:
galaxy
gene
genetic variation
geologic process
global warming
greenhouse gas

Used in grade 11:
gamma decay
glucose
gravitational field

h
Used in grade 5:
habitat
hazard
heat energy
hydrosphere

Used in grade 11:
homeostasis

i
Used in grade 5:
impact
increase
information
inherit
input
interaction
investigation

Used in grade 8:
identical
illuminate

Used in grade 11:
interference (of waves)
invasive species
irreversible
isotope

k
Used in grade 8:
kinetic energy

l
Used in grade 5:
landform
life cycle
light energy
limitation
liquid

Used in grade 8:
latitude
lava
light intensity
longitude
lunar

Used in grade 11:
light spectra

m
Used in grade 5:
magnet
magnetic force
marine
mass
mate
material
matter
measure
mineral
mixture
model
motion energy

Used in grade 8:
magma
magnetic field
magnitude
medium (of a wave)
melting point
microorganism
mitochondria
molecule
mutation
mutually beneficial

Used in grade 11:
macroscopic
mantle
meiosis
microscopic
mitosis
molar mass
mole
momentum

n
Used in grade 5:
nonrenewable

Used in grade 8:
natural hazard
natural resource
natural selection
nucleus (of a cell)
nutrient

Used in grade 11:
negative feedback

neutron
nuclear fission
nuclear fusion
nucleus (of an atom)

o

Used in grade 5:
object
observation
offspring
orbit
organism
output

Used in grade 8:
ocean current
oceanic crust
orbital period
orbital radius

Used in grade 11:
orbital velocity

p

Used in grade 5:
particle
pattern
physical property
planet
polar ice cap
pole (of a magnet)
pollen
pollution
population
precipitation
predator
prediction
prey
process
property

Used in grade 8:
percentage
photosynthesis
physical change
pixel
potential energy
probability
producer
product
proportion
protein

Used in grade 11:
photoelectric effect
photon
plate tectonics
polarity
positive feedback
proton

q

Used in grade 5:
quantity

r

Used in grade 5:
recycle
reduce
refine
reflect
relationship
renewable
repel
reproduction
research
resource
response
result
rock formation
rock layer
rotate
runoff

Used in grade 8:
reactant
refract
reservoir

Used in grade 11:
radiation
radioactive decay
radioactive isotope
radiometric dating
redshift
resilience
resonance

s

Used in grade 5:
scientist
sediment
sense receptor
shelter
similarity
simulation
solar energy
solid
solution (to a problem)
sound energy
source
species
speed
sprout
stability
state (of matter)
stationary
structure
substance
subsystem
support
surface
survive
system

Used in grade 8:
scale
sexual reproduction
solar system
solubility
solution (chemical)
stimulus
subduction
surroundings
synthetic

Used in grade 11:
selective advantage
surface tension
supernova
sustainability

t

Used in grade 5:
technology
temperature
toxin
trait
transfer
tsunami

Used in grade 8:
tectonic plate
thermal energy
tissue
transform
transmit
transpiration
trend

Used in grade 11:
trade-off
trophic level

u

Used in grade 5:
unbalanced force

Used in grade 8:
uplift

Used in grade 11:
ultraviolet light

v

Used in grade 5:
validity
variable
volcano
volume

Used in grade 8:
variation

Used in grade 11:
valence electron

w

Used in grade 5:
wave
wavelength
weathering
wetland
wind energy